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RESISTIVITY OF COPPER IN TEMPERATURE RANGE 20° C. TO 1450° C.*

BY

EDWIN F. NORTHRUP, Ph.D.,
Member of the Institute.

THE present paper is confined to a statement of the facts experimentally obtained respecting the resistivity of copper in the temperature range 20° C. to 1450° C., and to such description of the methods of measurement and apparatus employed as may be necessary to a clear understanding of the results here recorded. It is one report of the progress being made in the extended investigation undertaken by the writer[1] upon the electrical conduction of matter over extended temperature ranges.

I. SPECIAL DIFFICULTIES CONNECTED WITH MEASURING THE RESISTIVITY OF MOLTEN COPPER.

The accurate measurement of the resistivity of molten copper presents peculiar difficulties, and the ready measurement of the resistivity of this metal was constantly kept in mind when devel-

* Communicated by the author.

[1] Mr. V. A. Suydam, who joined the writer in this research, was called to another university and gave up his connection with the research before the method and measurements recorded here were made. The writer wishes to express his indebtedness to Mr. Suydam for his contribution to this general research in its earlier stages.

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oping the general method for measuring the resistivity of any molten metal, alloy, or molten salt. The method is now practically perfected for measuring copper, and may be applied with but slight modifications to the accurate and rapid measurement of any other molten metal or alloy or molten salt which melts under a temperature of 1600°C. or higher. Modifications of the method used for copper have been very successfully employed which are less costly and simpler to use, but which are confined to temperatures under 1100° C. A description of these modifications must be left to a future report.

The chief difficulty in tracing experimentally the resistivity curve of copper to temperatures high above its melting-point is due to its strong affinity for oxygen. If the molten metal oxidizes at any exposed surface it immediately absorbs its own oxide and its resistivity may increase 10 per cent. or more. The metal must be protected, therefore, from oxidation before and while the measurement is being made. It is also contaminated with hydrogen gas, and this precludes the use of a molybdenum wound furnace the winding of which is protected in a hydrogen atmosphere. Molten copper is inert in a CO atmosphere, and arrangements were provided for making the measurements in this atmosphere.

Minor difficulties result from the high melting-point ($1082.6 \pm 0.8°$ C.) of copper, and from its extreme fluidity when molten. The container for the molten metal must be constructed in a particular fashion and with great care to prevent the copper leaking from minute and unobtrusive cracks.

It is impossible to be certain, because of the tendency to contamination, that any single measurement, however carefully made, is correct. The result can only be known to be accurate when independent measurements, made at different times and in different containers, agree. In the early stages of the work measurements of the resistivity were made at some hundred degrees above the melting-point in which the most extreme care was used to be accurate, but which later proved to be many per cent. too high because the copper became contaminated by absorbing its own oxide and by alloying with the terminals (nickel or iron) then used.

All sources of error from these causes have been avoided in

the measurements here recorded, and independent determinations check with satisfactory precision.

II. REQUIREMENTS IN THE METHOD AND APPARATUS FOR MEASURING THE RESISTIVITY OF COPPER TO 1500° C.

For measuring the resistivity of copper in the range 20° C. to 1500° C. or higher one must have:

(*a*) An accurate electrical method of measuring resistance in which local thermal electromotive forces will be without influence. The method should preferably be a null method and read the resistivity at each recorded temperature directly and without corrections, in microhms per centimetre cube.

(*b*) Means for accurately reading the temperature.

(*c*) A container which will hold molten copper without danger of leaking, and which is provided with holes suitably arranged for current and potential leads, a hole for filling and one for holding a thermocouple, or for sighting down with an optical pyrometer. A special contrivance must be devised by which the extent of the apparent increase in resistivity due to shrinkage when the metal solidifies may be estimated and allowed for.

(*d*) A provision for making connection with the ends of the columns of molten metal which form the current and potential terminals. This connection must be made in a manner not to abstract much heat or contaminate the copper or have a high or uncertain resistance.

(*e*) Means for completely protecting the metal from air or other contaminating influences.

(*f*) Means for calibrating the container and setting the ratio coils of the bridge used so that the readings are given without requiring correction and directly in microhms per centimetre cube.

(*g*) Lastly, a tubular electrical furnace is required which will give, say, a temperature of 1600° C. without being strained, and a very uniform temperature over a considerable length of its tube. The temperature must be under perfect control and the furnace should not be injured with the vapors of any kind of metal. In the case of copper this furnace must operate with a CO atmosphere in its tube.

These various requirements and arrangements have all been

met and provided, and I shall briefly describe at this time all but the electrical furnace. This last piece of apparatus was specially developed for the research and has proved to be very satisfactory. It will be described in a later report, and it is planned to place it upon the market so it may be available to others.

The method, container, and furnace would have permitted the temperature to have been raised to at least 1800° C., but it was thought the thermocouple, then available, would be injured or have its calibration altered if the temperature was pushed higher than that used in the measurements. In fact, with the temperature used, as is later explained, the calibration was changed by some 10° C. in the second and third measurements.

III. METHOD AND APPARATUS.

The electrical method adopted for measuring the resistivity was the Kelvin-double-bridge method. Fixed ratio coils and a variable standard were employed. The variable standard used is one having a range, with even ratios, of 0 to 0.01 ohm. This piece of apparatus was in large part designed by the writer when with the Leeds & Northrup Company, and is sold by this company under the name "Variable Standard Low Resistance," Catalogue No. 4300. It is described in Pamphlet No. 40. The ratio coils which attach to the variable standard were called a and α and were set at a fixed even value. The ratio coils which attach to the unknown resistance were called b and β and were also set at a fixed value. Their value was so chosen by a rule to be described that the readings on the variable standard, when multiplied by 10^4, were directly in microhms per centimetre cube. The b and β values were obtained from an Otto Wolff box of ratio coils for use in Kelvin-double-bridge measurements. The box is listed in Otto Wolff's catalogue, paragraph 53.

In all cases, before a measurement was made of the resistivity of the sample, the current and potential leads from the measuring apparatus were attached to a standard 0.001 ohm made by Otto Wolff. If the apparatus measured this correctly (as it always did), assurance was given that the measuring part of the outfit was in proper working order and that no electrical leakage, bad contacts, etc., were present in a way to produce a hidden and constant error.

The galvanometer used with the Kelvin double bridge was a Leeds & Northrup high sensibility, narrow-coil galvanometer, Catalogue No. 2290. Its period is about 2½ seconds. Its sensibility, coil resistance, etc., were especially selected to be most suitable for the work in hand. The deflections were read with a lamp and scale.

Measurement of Temperature.

The temperatures were measured with a platinum *vs.* platinum + 10 per cent. rhodium thermocouple protected in a clear quartz tube. This couple was sent to the Bureau of Standards and a certificate obtained. A couple of this kind will not stand many heatings to 1400° C. or 1500° C. without changing its calibration.

The thermocouple-electromotive forces were read with a Leeds & Northrup potentiometer, Catalogue No. 7551, in conjunction with a specially-selected galvanometer of the same type as the one used with the Kelvin double bridge.

The cold junction of the thermocouple was kept at 0° C. by immersion in ice water contained in a Dewar flask. In this work, if the thermocouple changes its calibration, the fact, and the extent of the change at one temperature, becomes known. The solidification temperature of the metal is accurately known, and when solidification starts the resistance changes suddenly. At this moment the thermocouple should read the temperature of freezing of the metal, and by the amount it fails to do so has its calibration gone off.

The Container.

The construction of a container which would permit the measurement of the resistivity of any metal when in the molten state (excluding metals like tungsten and molybdenum, which melt at a temperature exceeding 2000° C.) proved to be an exceedingly difficult matter. The container, which is here described and which perfectly meets all requirements, was not arrived at without very many trials and rejections of unsuitable forms. Some of the conditions which had to be met are:

The selection of a material which will not melt or soften under a temperature of 2000° C.

A material which at the highest temperature employed has a

resistance far in excess of the resistance of the metallic circuit being measured.

A material which will not expand or shrink by an appreciable amount nor develop, on heating or cooling, the minutest crack.

The container must not give off at any temperature the slightest trace of gas.

It must be chemically inert in respect to any molten metal to avoid all contamination.

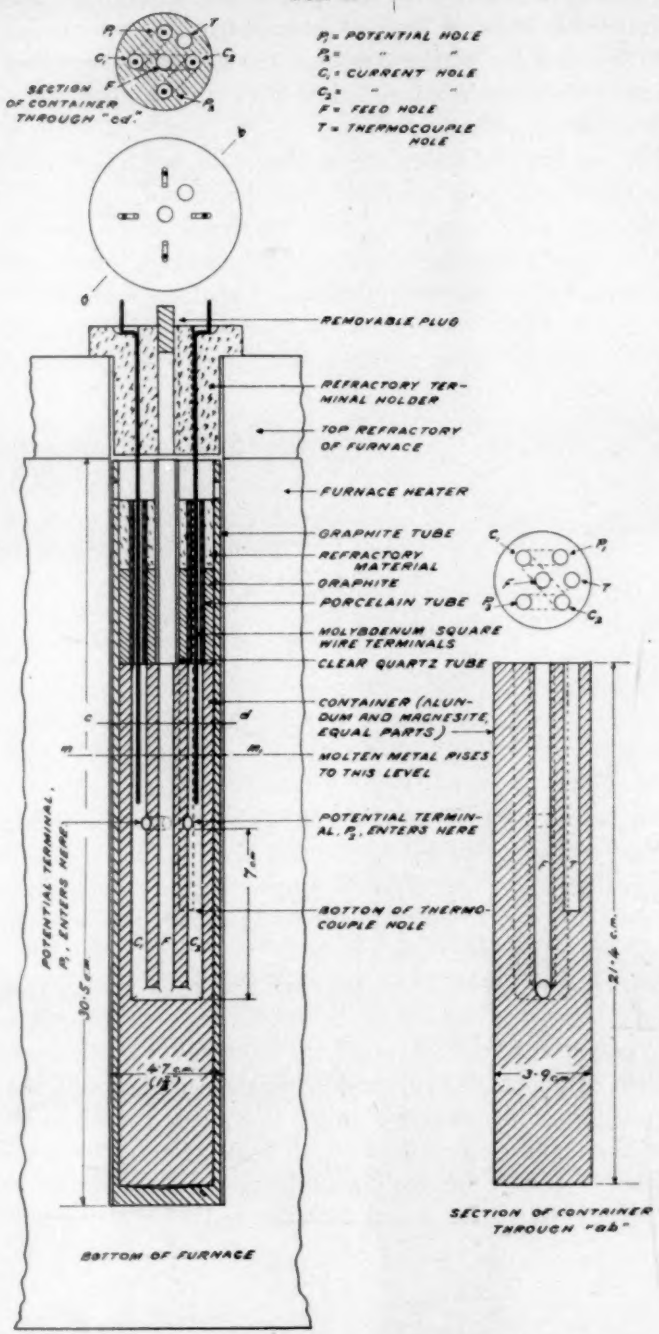
Lastly, this material must be in powdered form so it may be moulded and packed into any shape and drilled while soft. It must then, upon high heating (to 1400° C. or 1500° C.), become mechanically strong and very hard. Repeated heatings and coolings must produce no further change or modify its shape.

All compositions containing silica were rejected because silica interacts with certain metals (especially aluminum). All compositions containing carborundum, also porcelain, were rejected because when hot the resistance is low.

I have used pure alundum cement, grade RA 355, but this is prone to develop cracks and shrinks on a first heating. Pure magnesite was tried, but this is rather coarse-grained and difficult to make sufficiently coherent for drilling, etc., before firing. Successful containers may, however, be constructed out of either of these materials. But the best results were had when the containers were made of magnesite cement, finest ground, 50 parts by weight, and alundum cement, grade RA 355, 50 parts by weight. These two materials are sold by the Norton Company, Worcester, Mass. The magnesite and alundum are very thoroughly mixed together as dry powders. A very little water is then added and the mass again thoroughly mixed. This composition is then packed and pounded very hard in an iron cylinder, which separates longitudinally into two halves. The inner wall of the cylinder is lined before packing with bristol board, well oiled. This arrangement permits easy removal of the cylinder after packing and drying out in a gas oven.

It was early decided that the diameter of the columns of molten metal which was being measured should be as great as 6 or 7 millimetres, and this, together with a 7-millimetre hole for insertion of the thermocouple, determined the diameter of the cylinder of refractory material. Fig. 1 shows, with all dimen-

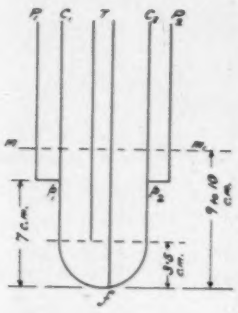
FIG. 1.


P1 = POTENTIAL HOLE
P2 = " "
C1 = CURRENT HOLE
C2 = " "
F = FEED HOLE
T = THERMOCOUPLE HOLE
SECTION OF CONTAINER THROUGH "cd."
REMOVABLE PLUG
REFRACTORY TERMINAL HOLDER
TOP REFRACTORY OF FURNACE
FURNACE HEATER
GRAPHITE TUBE
REFRACTORY MATERIAL
GRAPHITE
PORCELAIN TUBE
MOLYBDENUM SQUARE WIRE TERMINALS
CLEAR QUARTZ TUBE
CONTAINER (ALUNDUM AND MAGNESITE EQUAL PARTS)
MOLTEN METAL RISES TO THIS LEVEL
POTENTIAL TERMINAL, P2, ENTERS HERE
BOTTOM OF THERMOCOUPLE HOLE
POTENTIAL TERMINAL, P1, ENTERS HERE
30.5 cm.
7 cm.
4.7 cm. (1 7/8")
BOTTOM OF FURNACE
21.4 c.m.
3.9 cm.
SECTION OF CONTAINER THROUGH "ab"

sions given, not only the completed container, but also the graphite tube with the bottom end closed into which the container fits, and the arrangement of the top cap of graphite and refractory material employed, and the furnace-tube cover with the terminals in place.

The six vertical holes are drilled with a ¼-inch wood bit before the container is removed from its mould. The container is then dried out in a gas oven and removed from its mould. The cross holes are then located and drilled. Rods of metal which fit the holes are then inserted in them. The three side holes which make an exit to the outside of the cylinder are then packed with *the same* composition as the container is made of. The rods are

FIG. 2.



removed and the container is placed in the graphite tube, lowered into the furnace, and fired for several hours at a temperature of not less than 1400° C. When removed it is strong and very hard, has no cracks and is ready for use, and possesses all the requisite qualities above enumerated.

Referring to the skeleton diagram, Fig. 2, C_1 and C_2 are holes for the insertion of the current terminals, P_1 and P_2 for insertion of the potential terminals, F a hole for feeding in the metal (in the form of about No. 12 wire) to be measured, and T the hole for insertion of the thermocouple. When the container is filled the molten metal rises to about the height indicated by the dotted line mm_1. The resistance path of the metal measured is the path p_1fp_2. It will be noted that the end of the thermocouple

reaches to the mid point from where the potential holes tap off and the bottom of the metal columns. The axial distance of the thermocouple from the axis of the container is the same as the axial distance of the metal columns. Thus the thermocouple records quite precisely the mean temperature of the metal circuit p_1fp_2.

The Terminals.

The writer found by trial that molybdenum wire (about 2 mm. diameter square wire was used) is a most satisfactory material to use for terminals to make connection with the tops of the columns of molten metal. This wire will not alloy at high temperatures in gold, mercury, bismuth, tin, lead, zinc, cadmium, antimony, aluminum (only slightly and at a high temperature), or copper, and this is presumably the case for all metals outside the group iron, nickel and cobalt. The terminals used in measuring copper were of this material, and after several hours' immersion in molten copper at over 1400° C. the sharp edges of the square wire were not eaten or dulled in the least.

Prevention of Oxidation.

Copper is unaffected in a CO atmosphere. Hence by placing the container in a graphite tube with a graphite piece over the top (which further aids in maintaining the entire container at a uniform temperature), and then using a furnace which develops in its interior only a CO atmosphere, the copper is kept entirely away from oxygen. When prepared for feeding into the container, the wire used is cut into short lengths, about 15 centimetres, and dropped into the feed hole of the container through a small hole in the furnace cover piece. The small hole is immediately plugged, and thus no air can possibly reach the copper. In this way copper is fed into the container until a circuit is established through the current leads attached to the Kelvin bridge.

Calibration of the Container.

The container is calibrated so that the readings may be obtained directly in resistivity, microhms per centimetre cube, as follows:

For this purpose the container is filled with pure mercury and the resistance is measured at a known temperature.

Let R_t = the resistance of the container filled with mercury and ρ_t = the known specific resistance of mercury. Then

$$R_t = K\rho_t \quad \ldots\ldots (1)$$

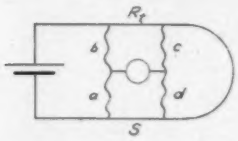
where K is the constant of the container. Then if R'_{t_1} is the resistance of the container when filled with the metal under test at a temperature t_1, we have

$$R'_{t_1} = K\rho'_{t_1} \quad \ldots\ldots (2)$$

where ρ'_{t_1} is the required resistivity at temperature t_1 of the metal under measurement. From Equations (1) and (2)

$$\rho'_{t_1} = \frac{R'_{t_1}}{R_t}\rho_t \quad \ldots\ldots (3)$$

FIG. 3.



By the law of the Kelvin double bridge

$$R'_{t_1} = \frac{b}{a}S \quad \ldots\ldots (4)$$

where b and a are the values of the ratio coils (see Fig. 3), and S is the setting of the variable standard which gives a balance. Putting this value of R'_{t_1} in Equation (3) gives

$$\rho'_{t_1} = \frac{b\rho_t}{aR_t}S \quad \ldots\ldots (5)$$

The scale of S is laid off in ohms and its maximum reading is 10^{-2} ohms. It is evident that if $\frac{b\rho_t}{aR_t} = 1$ the readings of S will give the resistivities directly in ohms. If the readings of S are multiplied by 10^6, then ρ'_{t_1} is given in microhms. Hence to have

the bridge read in microhms we must place $\frac{b\rho_t}{aR_t} 10^6 = 1$. If, because of the limit of the variable standard, we again multiply its readings by 10^4 we should then place

$$\frac{b\rho_t}{aR_t} 10^6 \times 10^{-4} = 1.$$

This gives

$$b = \frac{R_t}{\rho_t} a\ 10^{-2} \text{ ohms} \quad \ldots\ldots (6)$$

as the proper setting for the ratio coil b (and the ratio coil β). If when b has this value a balance is obtained when the variable standard reads, for example, 0.001734, the resistivity is 17.34 microhms per centimetre cube. The value of a is arbitrarily selected, the resistance R_t of the mercury in the container is measured at the temperature t, and the resistivity of pure mercury at the temperature t is known.

In the measurement of copper made October 29, 1913, the values found and used for obtaining the value of b were:

a = 1000 ohms, by selection.

$R_t = 7736.2 \times 10^{-6}$ ohm = resistance of mercury in container when at a temperature of 23° C.

$\rho_t = 96.074 \times 10^{-6}$ ohm = the resistivity of mercury at 23° C.

(The values of the resistivity of mercury used are those of Kreichgauer and Jaeger, and the mercury used was some which was furnished me by Prof. G. A. Hulett. It had been three times distilled in vacuum.)

These values placed in Equation (6) give $b = 805.23$.

The Furnace.

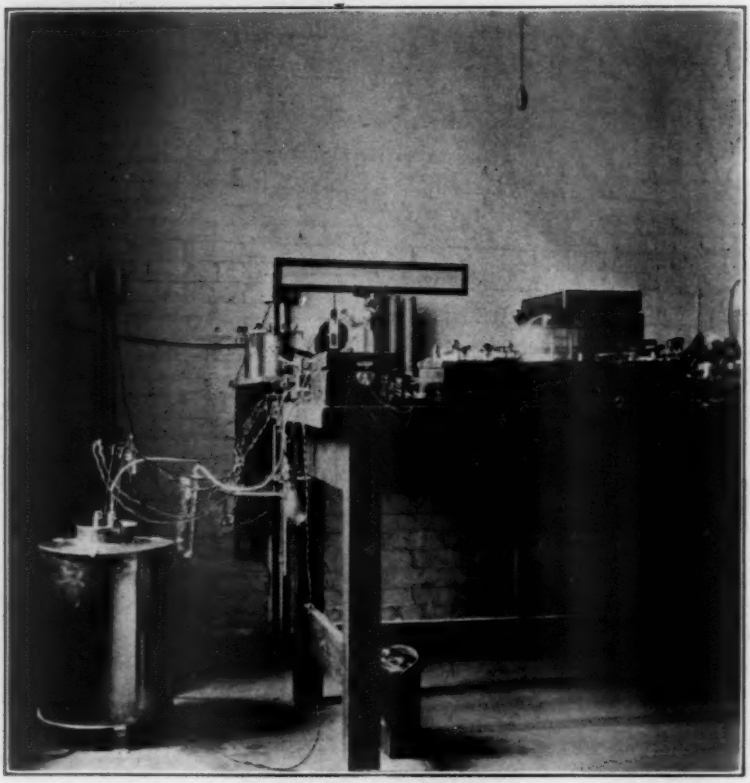
The furnace employed was especially developed for this research. It is of the tubular type with heating tube 30 centimetres long and stands with the tube vertical. The length of tube which heats uniformly is about twenty centimetres. The internal diameter is 4.762 centimetres. The furnace will melt platinum without being destroyed. It automatically develops in its tubular space

an atmosphere of pure CO. This furnace serves for measuring the resistivities of all substances which melt under 1700° C. or possibly 1800° C.

IV. PROCEDURE FOLLOWED IN MEASURING COPPER.

In planning this measurement it was hoped that a precision might be obtained in which the greatest departure from the mean

FIG. 4.



Furnace and accessories.

of different determinations of the resistivity of copper in the molten state would not exceed 0.25 of one per cent. The results, as will appear later, show that a precision better than this has probably been obtained.

In making a measurement the ordinary course of procedure

is to bring the container to a high temperature, above the melting-point of the metal, fill the container and take readings of resistivity and temperature while the furnace very slowly cools. So long as the metal is in the molten state the actual values as well as the relative values at different temperatures of the resistivities will be correctly measured. When, however, solidification occurs the cross section, but not the length, of the metal which lies between the potential points will diminish, due to the contraction of the metal which occurs when it passes from the liquid to the solid state. If the resistivity of the metal has been determined previously at 20° it will always be found (in the case of metals which contract upon solidification) that when this temperature is reached the measured resistivity is several per cent. too high. The rate of change of the resistivity with temperature after solidification occurs is given correctly, however. If, therefore, we are to trace the true resistivity curve through the solid into the liquid state we must draw a curve through the point which gives the resistivity at 20° C. and below the resistivity curve obtained upon cooling after the metal has solidified. In the determination of the resistivity curve of copper an independent determination was made, as an extra precaution, of the increase in resistivity with temperature as the temperature was raised from 20° C. to a point where the metal between potential points was all melted. This was accomplished by making a metal form of No. 3 B. and S. copper rod which had approximately the same size and shape as the channels in the container which form the current and potential holes (see also Fig. 2). The arrangement constituted a rod of copper bent into the form of a hairpin with two other rods, serving for potential terminals, attached to it at about 8 centimetres from the lower rounded end. This copper-form was imbedded in a cylinder of alundum cement packed very hard. A suitable hole was drilled for the insertion of a thermocouple. The cylinder was 30 centimetres long and 5.72 centimetres in diameter. This was wound from one end to the other with a strip of molybdenum about 0.8 centimetre wide and 0.2 centimetre thick. The cylinder so wound was placed in a vessel and packed with a refractory heat-insulating material. The temperature was then very slowly raised by passing current through the molybdenum winding, and the resistance

and temperature were measured at frequent intervals. As might be expected when the metal melted, the expansion opened longitudinal cracks in the cylinder and the molten metal ran out and brought the measurements to an end. This did not occur, however, until the curve had been traced from 20° to 1143° C. The resistivity of the sample of copper was also very carefully determined at 20° C., and thus data were obtained for tracing the resistivity curve from room temperature to a temperature where the metal between potential points was all molten (see Curve I).

Since the per cent. conductivity of copper is the best index of the chemical purity, no chemical or other tests were made of the purity of the copper used. The copper used in the measurement of the resistivity in the solid state, just described, was selected from one lot and the copper used in the two independent determinations, where the resistivities were traced from the molten state to 20° C., was taken from another lot. The conductivity by Matthiessen's meter millimetre standard was, for the copper used in the first determination, 99.71 per cent., and for the copper used in the second and third determinations, 99.39 per cent.

V. TABLES, DATA AND CURVES.

Some of the data obtained are more accurate than can be represented in curves which it is practicable to reproduce in a printed article. For this reason and because of the additional information given I shall now give tables which present the data as they were obtained in three determination.

The data recorded in Tables I, II, and III are plotted in the curves. Curve I is a plot of the resistivities ρ'_t in range 20° C. to 1143°C. obtained from copper in the solid state with rising temperature, Curve II belongs to the second determination, the resistivities being measured with falling temperature from 1394° C. to 20.5° C., and Curve III belongs to the third determination, the resistivities being measured with falling temperature from a recorded temperature of 1443° C. to 22.3° C.

VI. INTERPRETATION OF RESULTS.

Examination shows that below a temperature of 1143° C. the three curves do not coincide. This lack of coincidence is explainable and is not prejudicial to the accuracy of the results.

TABLE I.

Determination of Resistivity of Copper in Range 20° C. to 1143° C.

Date, March 20, 1913.

Observers: E. F. Northrup, Mrs. E. F. Northrup, V. A. Suydam.

NOTE.—The sample was a No. 3 B. and S. soft copper rod bent into the form of a hairpin, and the resistance was measured between potential points with a Kelvin double bridge. The temperatures were measured with the certified platinum *vs.* platinum + 10 per cent. rhodium thermocouple. All measurements were made with rising temperature. An independent determination gave the resistivity of the copper used in this measurement as 1.7290 microhms at 20° C. As the resistivity of the copper used in the second and third measurements was 1.7347 microhms at 20° C., all values of resistivity ρ'_t obtained in this measurement have been multiplied, for purposes of comparison, by $\frac{1.7347}{1.7290} = 1003$ and called ρ'_t.

Degrees C. t	Resistance in microhms	Resistivity ρ_t in microhms	Resistivity ρ'_t in microhms	Remarks
24.0	136.7	1.757	1.761	Began 3:05 P.M.
71.4	161.4	2.075	2.081	
117.9	186.1	2.392	2.397	Ratio $\frac{b}{a} = \frac{400}{10,000}$
148.0	208.4	2.678	2.686	
238.0	253.7	3.261	3.270	
298.0	285.1	3.665	3.676	
353.0	315.3	4.053	4.065	
435.0	358.6	4.609	4.622	Time 3:40 P.M.
495.0	391.2	5.029	5.044	
543.0	420.5	5.406	5.422	Ratio $\frac{b}{a} = \frac{800}{10,000}$
647.0	482.0	6.195	6.213	
763.0	558.5	7.179	7.200	Time 7:50 P.M.
881.0	639.0	8.213	8.237	Time 8:05 P.M
945.0	688.0	8.843	8.870	
1001.0	733.0	9.421	9.448	Ratio $\frac{b}{a} = \frac{900}{1800}$
1041.0	774.0	9.948	9.978	
1066.0	813.0	10.450	10.480	
1082.0	914.0	12.020	12.090	Time 8:50 P.M.
1088.0	1025.0	13.170	13.210	
1093.0	1150.0	14.780	14.820	
1097.0	1250.0	16.060	16.110	
1100.0	1350.0	17.350	17.400	
1103.0	1500.0	19.280	19.340	
1117.0	1650.0	21.210	21.270	Time 9:15 P.M.
1143.0	1697.5	21.820	21.880	Container leaked.

TABLE II.

Determination of Resistivity of Copper in Range 1394° C. to 20.5° C.

Date, October 10, 1913.

Observers: E. F. Northrup, Mrs. E. F. Northrup.

NOTE.—By an independent determination the resistivity of the copper used in this measurement was found to be 1.7347 microhms at 20° C. Copper of 100 per cent. conductivity has a resistivity at 20° C. of 1.7241 microhms (Bulletin No. 31 of Bureau of Standards, p. 9). Hence the conductivity of copper used in test is $\frac{1.7241}{1.7347} 100 = 99.39$ per cent.

Only measurements made with falling temperature are here recorded. Container No. III used.

Thermo-couple e. m. f. in microvolts	Temperature in degrees C.	Resistivity in microhms	Time	Remarks
13,464	1394	23.78	4:11 P.M.	Measuring current 10 ampères, b = 635.4 ohms, a = 1000 ohms.
12,830	1340	23.39		
12,422	1307	23.12		
11,693	1244	22.61	4:20 P.M.	Resistance of container filled with mercury = 6102 microhms at 22.7°C. $\rho_{22.7}$ = 96.045 microhms.
10,974	1182	22.11		
10,250	1120	21.61		
9,869	1087	21.31		
9,800	1082	20.57		
9,731	1076	19.10		
9,684	1072	17.59		
9,650	1067	16.58		
9,624	1065	15.58		
9,596	1064	14.57		
9,512	1056	11.56		
9,440	1050	10.35		
9,190	1027	10.05	4:44 P.M.	
8,940	1005	9.85	"	
8,829	993	9.748	4:49 P.M.	
8,590	978	9.547	4:52 P.M.	Set b = 635.4, a = 10,000.
7,998	920	9.045		
2,591	364	4.572		
2,570	361	4.531	10:05 P.M.	
	55.5	2.382	2:00 P.M.	10/11/'13. Temperature taken with mercury thermometer. Read 11/14/'13.
	20.5	2.133		

TABLE III.

Determination of Resistivity of Copper in Range 1443° C. to 20° C.

Date, October 29, 1913.

Observers: E. F. Northrup, Mrs. E. F. Northrup.

NOTE.—Copper from same lot as used in the measurement made October 10, 1913. Container No. V used.

Only measurements made with falling temperature are here recorded. True resistivity at 20° C. = 1.7347 microhms.

Thermo-couple e. m. f. in microvolts	Temperature in degrees C.	Resistivity in microhms	Time	Remarks
14,042	1443	24.17	11:25 A.M.	Resistance of container filled with mercury = 7736.2 microhms at 23°C. $\rho_{23} = 96.074$. Set $b = 805.2$ ohms, $a = 1000$ ohms.
14,023	1441	24.16		
13,711	1415	24.00		
12,912	1347	23.50	11:39 A.M.	
12,175	1285	23.00		
11,450	1223	22.50	11:53 A.M.	
10,698	1158	22.00	12 M.	
9,963	1096	21.50		
9,795	1081	21.40		
9,765	1078	21.30		
9,746	1077	21.10		
9,702	1073	20.50	12:17 P.M.	
9,674	1070	20.00		
9,644	1067	19.50		
9,622	1065	19.00		
9,600	1064	18.50		
9,580	1063	18.00	12:19 P.M.	
9,560	1060	17.50		
9,540	1058	17.00		
9,523	1056	16.50		
9,504	1055	16.00		
9,490	1054	15.50		
9,473	1052	15.00		
9,455	1051	14.50		
9,438	1050	14.00		
9,420	1047	13.50		
9,400	1046	13.00		
9,385	1045	12.50		
9,364	1043	12.00		
9,328	1040	11.00		
9,300	1038	10.50		
9,258	1034	10.32	12:26 P.M.	
9,200	1028	10.24		
8,950	1007	10.00		Made $a = 10{,}000$.
8,870	998	9.942		
8,715	985	9.800		
8,180	937	9.330		
7,792	900	9.000	12:55 P.M.	
6,605	786	8.000		
4,192	540	6.020	3:35 P.M.	
4,151	525	5.987		
3,262	440	5.254	5:02 P.M.	
1,490	229	3.716	9:38 P.M.	
	223	2.243	8:50 A.M.	Reading made 10/30/'13. Temperature by mercury thermometer.

Curves II and III begin to separate at the solidification temperature because the thermocouple which was used in obtaining the data for Curve II had had its calibration changed by being heated to the high temperature reached in this and the third measurements. This is proved by the fact that at the moment the copper started to solidify in the third measurement the registered temperature was about 1072° when it was 1082.6°. The thermocouple was accidentally destroyed during the close of the measurement, or this statement would have been further verified.

If all the high temperatures of Curve III are moved 10° to the right the coincidence of Curves II and III becomes practically perfect. With this understood, the two determinations, made at different times and in different containers having different constants, very closely check each other. Curve I necessarily, by the method of measurement used, lies below Curves II and III when the copper is in the solid state. That it does not exactly parallel this curve from temperature 20° C. to 1000° C. may perhaps be explained in part by the fact that the conductivity of the copper used for getting Curve I was 99.71 per cent., as against 99.39 per cent. for the copper used in getting Curves II and III, and consequently had a different coefficient. Possibly, also, expansion of the copper in the one case and contraction in the other cases have an important effect on the slope of the curves, and the loss of heat by conduction toward the terminal attachments may have introduced some uncertainty into the data of Table I at the higher temperatures.

It will be noted that with rising temperature the curve begins to bend upward decidedly at the melting temperature of copper, but the resistivity is not that of molten copper until a temperature of about 1143° C. is reached. On the other hand, with the falling temperature employed in obtaining Curves II and III the resistivity abruptly diminishes very closely to the solidification temperature of copper, but the resistivity of solid copper is not reached until the temperature has lowered (in the case of Curve II) to 1050° C. These features in the curves are to be explained by the fact that, so far at least, it has been found impossible to make the temperature perfectly uniform over the entire length of metal between potential points. Melting or solidification does not, therefore, take place at the same instant over the entire length of metal being measured. If such occurred the change in resistance in passing from solid to liquid or from liquid to

solid would be abrupt and would be represented by a perpendicular line, as shown in Curve IV. This curve has been drawn to represent, according to the writer's judgment, what is probably the true resistivity curve for copper from 20° C. to 1450° C.

It is difficult to assign the probable precision to the results shown by Curve IV, but the writer believes he is conservative in stating that in the liquid state the error does not exceed ¼ or at the most ½ per cent.

Should any one repeat these measurements it must be borne in mind that the least oxidation of the copper introduces a contamination which may greatly raise the resistivity in the molten state. In an early attempt to measure copper, iron wires being used for terminals and the copper being exposed to oxidation, the resistivity obtained at 1241° C. was 36.2 microhms, whereas my present value is 22.60 microhms. Another determination was made in which there was no recognizable cause for contamination other than such oxide as formed at the top surfaces of the liquid columns. At 1432° C. the resistivity found was 27.6 microhms, whereas my present value at this temperature is 24.10 microhms. Thus it is concluded that the oxidation raised the resistivity about 14.5 per cent.

Using data taken from Curve IV we can find the ratio of the resistivity just after fusion to the resistivity just before fusion. Taking the former at 21.3 and the latter at 10.2, this ratio becomes 2.08_8.

These measurements suggest the possibility of determining the shrinkage which takes place when the metal solidifies, also when it further cools. If this is possible the calculation would be made as follows: Let it be assumed that the length of the channel in the refractory container from potential point to potential point remains constant and that such contraction as takes place in the metal measured is in cross section only. Let it be further assumed that the contraction in section is uniform from one potential point to the other. Then

Let S_s = cross section of metal when it fills the channel and S_c = cross section of metal when contracted.

Let R_s = resistance of metal when its cross section is S_s and R_c = resistance of metal when its cross section is S_c.

Then $\frac{S_s - S_c}{S_s}$ is the proportionate part of the original cross section by which the metal has contracted. It is the shrinkage.

If ρ_t is the true resistivity of a metal at a temperature t, then

$$R_s \propto \frac{1}{S_s}\rho_t \text{ and } R_c \propto \frac{1}{S_c}\rho_t$$

where 1 is the length of the channel. Thus

$$S_s \propto \frac{1}{R_s} \text{ and } S_c \propto \frac{1}{R_c},$$

and hence, calling C_t the contraction in section at temperature t, we have

$$C_t = \frac{S_s - S_c}{S_s} = \frac{R_c - R_s}{R_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Now the setting given the variable standard to secure a balance, and which we call the resistivity of the metal, will be directly proportional to the reistance of the metal between potential points. Hence $\rho_s \propto R_s$ and $\rho_c \propto R_c$ where ρ_s is the resistivity (which is the true resistivity obtained from Curve IV) obtained as the metal is heated, and ρ_c is the resistivity (apparent, which Curve II gives) obtained after the metal has solidified. We have thus

$$C_t = \frac{\rho_c - \rho_s}{\rho_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

for any particular temperature below the solidification temperature. For a temperature of 1000° C. we find

$C_{1000} = \frac{9.80 - 9.42}{9.80} = 0.0388$ = shrinkage in section at 1000° C. when metal changes from liquid to solid.

For a temperature of 20° C.

$$C_{20} = \frac{2.129 - 1.735}{2.129} = 0.185+$$

These results may not mean much, but suggest interesting possibilities in the way of measuring the shrinkage of metals when they pass from liquid to solid.

The above discussion and the differences in the results recorded in Curve I, and in Curves II and III below the solidification point, raise the complex question as to what constitutes the true relation in these measurements between the resistivity on a basis of a constant mass and on a basis of a constant volume of the metal. A further discussion of the matter must be reserved until

the writer has obtained more facts and a clearer understanding of the interpretation to be put upon the observed data.

If we express the increase in resistivity of copper in the molten state by the relation

$$\rho_{t_1} = \rho_t \left[1 + \beta_t (t_1 - t) \right]$$

we find

$$\beta_t = \frac{\rho_{t_1} - \rho_t}{\rho_t (t_1 - t)} \qquad (9)$$

where we are to understand by ρ_t the coefficient calculated when the lower temperature is t.

Let $t = 1100$ degrees. Then we find, calling $\rho_t = 21.43$ microhms,

$$\beta_t = \frac{23.39 - 21.43}{21.43(1340 - 1100)} = 0.000381.$$

In Table IV below those values are selected which, in the writer's judgment, have the highest probability of being correct.

TABLE IV.

Values Found for Copper of 99.39 Per Cent. Conductivity.

Temperature degrees C.	Resistivity in microhms per cm. cube	Ratios ρ_t/ρ_{t_1}	Notes
20	1.7347		
1000	9.42	$\rho_{1000}/\rho_{20} = 5.429$	Metal solid.
1082.6	10.20		
1082.6	21.30	$\frac{\rho_m}{\rho_s} = 2.088$	Metal molten.
1100	21.43		
1340	23.39		
1450	24.22	$\rho_{1450}/\rho_{20} = 13.96$	Highest measurement was 1443° C.

The writer expresses his indebtedness to his wife for her assistance in the laboratory, both in preparing for the measurements and in taking observations.

PALMER PHYSICAL LABORATORY,
PRINCETON, N. J.

Canadian Timber. ANON. (*Eng.*, xcvi, 2487, 289.)—The forests of Canada consist, for the greater part, of coniferous species; viz., pine and spruce, with hemlock on the east, and Douglas fir, western hemlock, and western larch in the west. In the east the hardwoods comprise poplar, birch, beech, and maple, with some elm, ash, and a few other minor species. Only in Southern Ontario is there anything like the variety of hardwoods which are found in the Appalachian region of the United States. The forestry branch of the Canadian Ministry of the Interior has established a system for the collection of statistics with respect to the various wood manufacturers of the Dominion. The quantities and values of the wood used in 1911 were: Lumber, 4,918,202,000 feet, of the value of $75,830,954; square timber for export, 34,500 tons, worth $766,406; lath, 965,235,000 pieces, valued at $2,212,226; shingles, 1,838,474,000 pieces, worth $3,512,078; pulp wood manufactured in Canada, 672,288 cords, of the value of $4,388,024; pulp wood exported (unmanufactured), 847,939 cords, valued at $5,340,592; cooperage (slack), 147,374,000 pieces, value $1,465,702; cooperage (tight), 5,762,000 pieces, value not fully known; railway sleepers, 13,683,770 pieces, value $5,237,424; and poles, 585,703 pieces, value $1,056,277. The Douglas fir of the Western Provinces has made rapid progress, and now stands third in the list of lumber woods. Hemlock, once entirely passed by the log makers, now stands fourth in point of quantity sawn for lumber. While spruce still leads among woods used for pulp, balsam fir is also being more and more resorted to for the same purpose. For railway ties, jack pine has replaced cedar.

Reflection of X-Rays. M. DE BROGLIE. (*Nature*, xci, 161.)—This article includes interesting diagrams of the distribution of the pencils of X-rays due to the scattering of a very narrow beam by various crystals. The author considers that the transmitted "spots" of Friedrich, Knipping, and Laue are due to the same cause as the reflected spots obtained by allowing a beam of X-rays to fall on a face of a crystal at almost grazing incidence. The results show that spots produced on a photographic plate by the pencils scattered from the crystal are generally striated by parallel fringes both in the case of reflected and transmitted spots. Similar phenomena are obtained with ordinary light and two ordinary gratings (200 lines to the millimetre), when the incident beam forms similar angles of incidence with the plane of the gratings.

A New Soft Solder. ANON. (*Met. and Chem. Eng.*, xi, 8, 438.)—This new soft solder was patented by John T. Dwyer, of St. Louis, Mo., and is said to possess superior properties, and to be less costly than ordinary lead-tin solder. It contains approximately 41.5 per cent. of tin, 0.02 per cent. phosphorus, 2 per cent. antimony, and the balance is lead.

SOME PHENOMENA OF FLUID MOTION—THE CURVED FLIGHT OF A BASEBALL.*

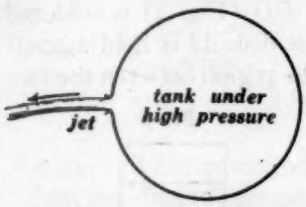
BY

W. S. FRANKLIN, Sc.D.,

Professor of Physics, Lehigh University.
Member of the Institute.

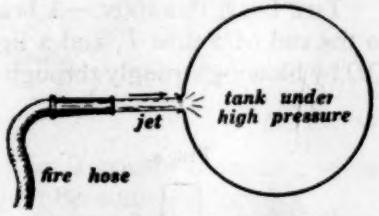
THE steady curvature of path of a rapidly spinning baseball in flight is explained on the basis of a principle which was first enunciated by Daniel Bernoulli several hundred years ago. Bernoulli's principle is illustrated in Figs. 1 and 2. In a stream of water or air the pressure is high where the velocity is low, and the pressure is low where the velocity is high. In the following discussion it is not desired to take account of gravity, and there-

FIG. 1.



In the tank the water has high pressure and low velocity; in the jet the water has low pressure and high velocity.

FIG. 2.



A fancy method for pumping water into a steam boiler. In the jet the water has high velocity and low pressure, and as the rapidly moving water pushes itself into the tank where the pressure is high it loses its velocity.

fore Bernoulli's principle is stated for the case of a horizontal stream. Also the effects of friction are ignored; as here stated, therefore, Bernoulli's principle applies only to approximately frictionless fluids, and indeed the principle applies only to cases of steady flow.[1]

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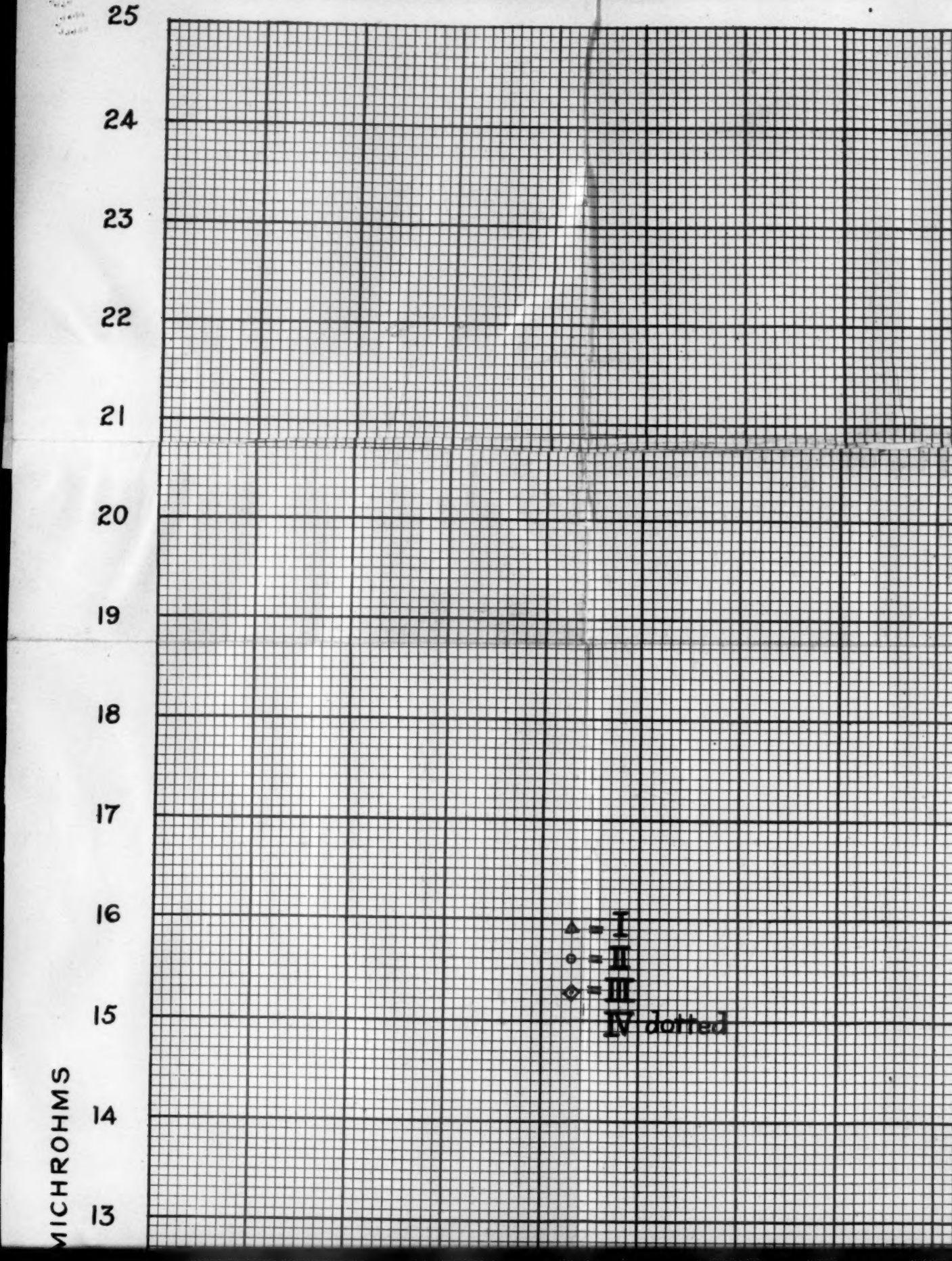
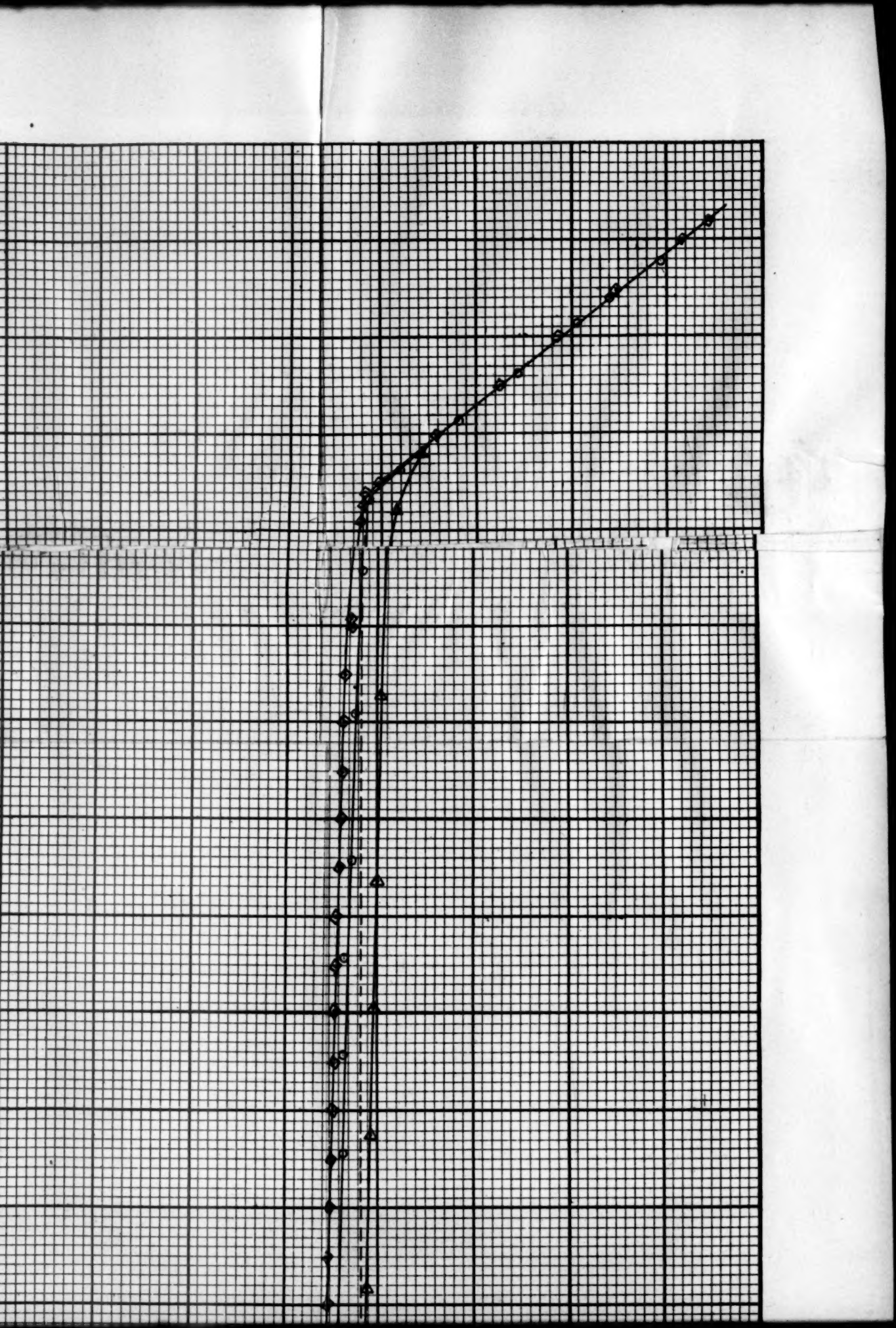
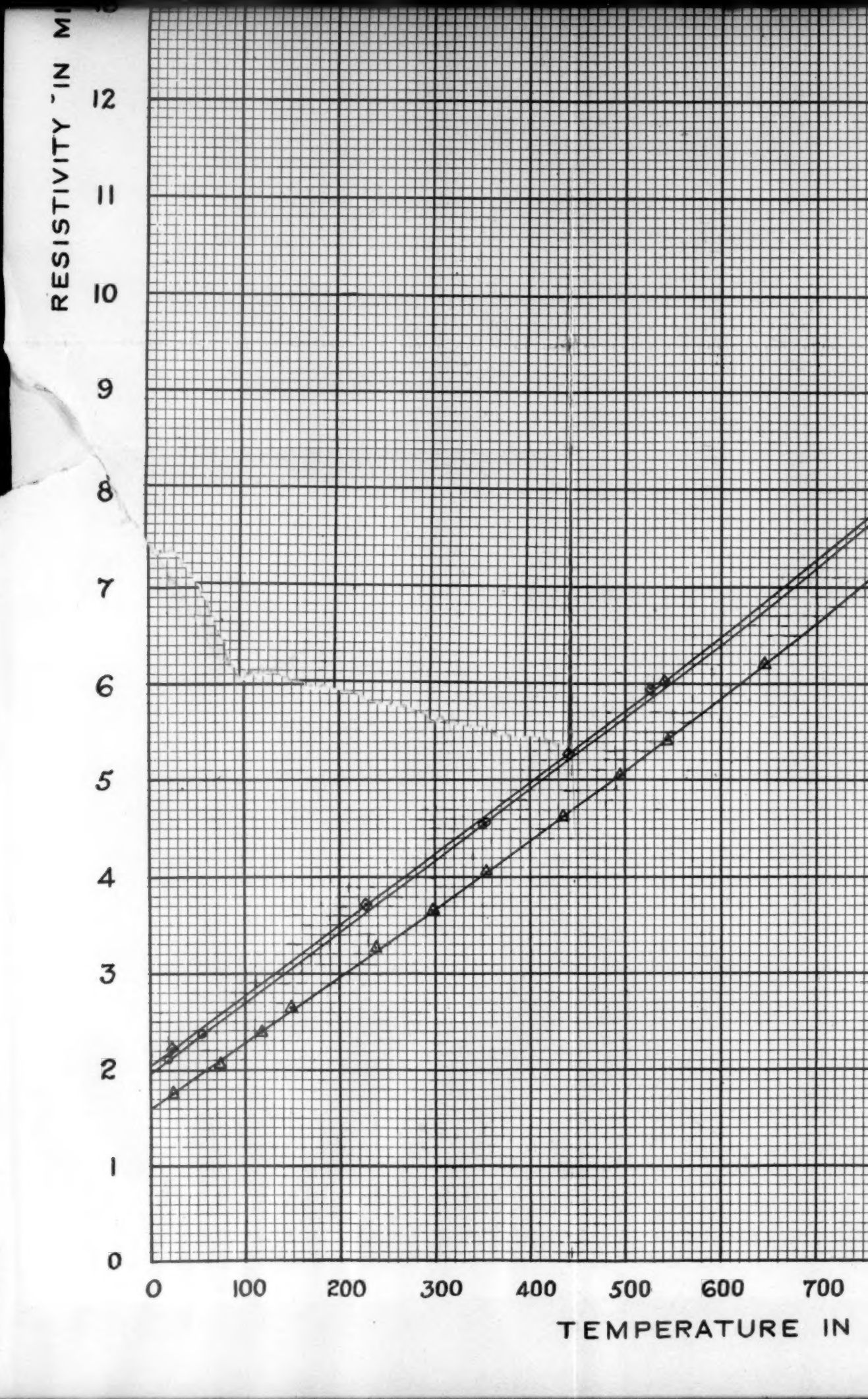
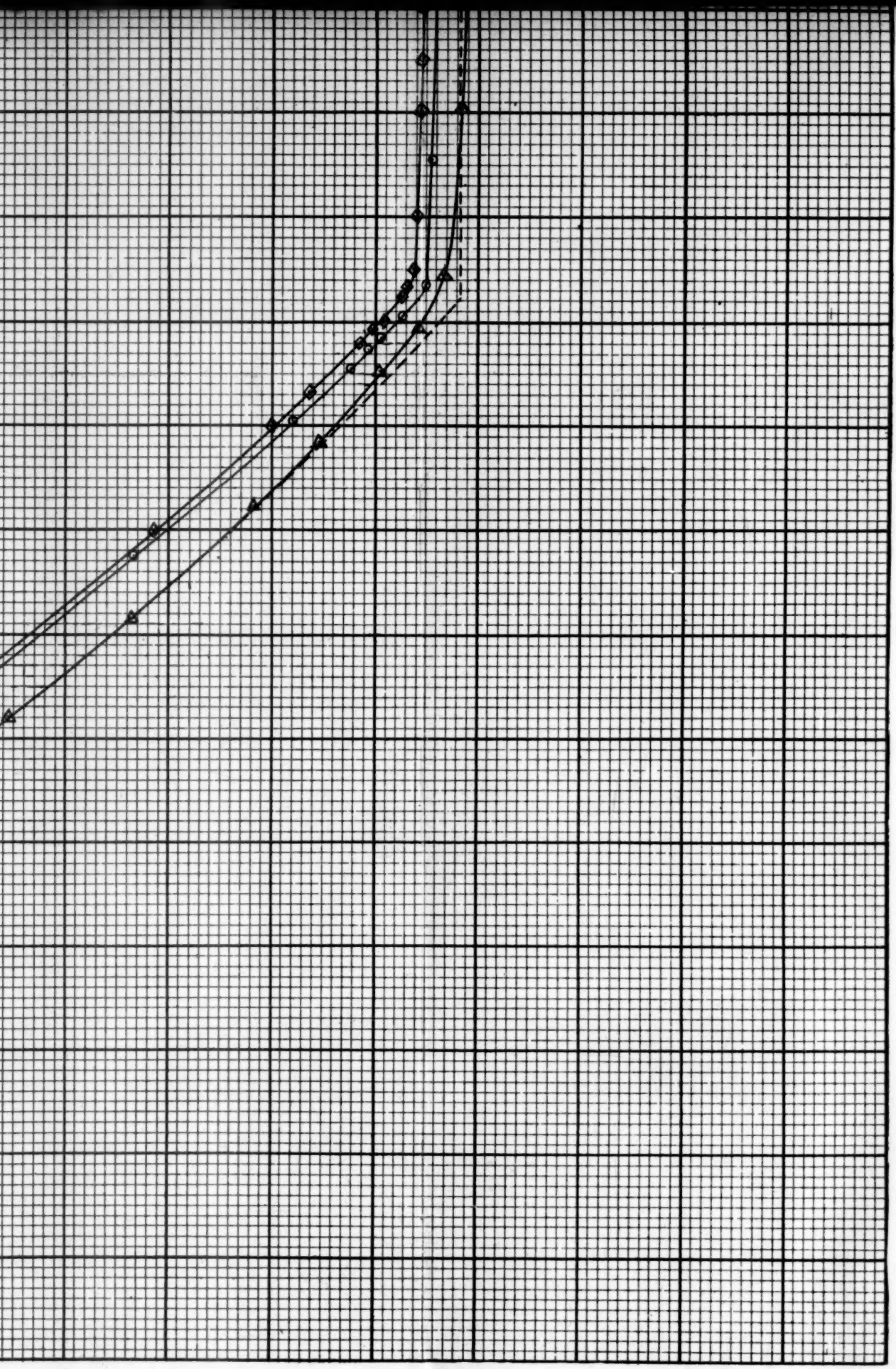
* Communicated by the author.

[1] A further limitation of Bernoulli's principle is exemplified by the motion of the fluid in a cream separator. The pressure is greatest near the outer walls of the rotating bowl where the velocity is greatest. Bernoulli's principle does not apply to rotational fluid motion.


25
24
23
22
21
20
19
18
17
16
15
14
13
MICROHMS
△ = I
○ = II
◇ = III
IV dotted

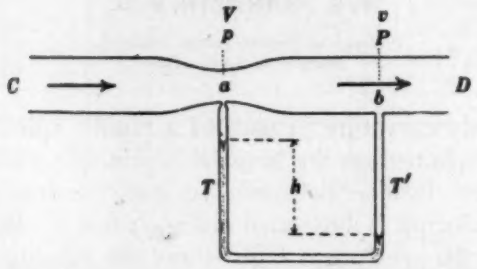



RESISTIVITY IN M
12
11
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
TEMPERATURE IN


700
800
900
1000
1100
1200
1300
1400
1500
RE IN DEGREES C.

THE VENTURI TUBE.—Air is blown through a tube *CD* (Fig. 3). The velocity of the air is larger at *a* than at *b;* therefore, according to Bernoulli's principle, the pressure of the air is larger at *b* than at *a*. This excess of pressure at *b* is shown by the difference in level of the liquid in the two tubes *T* and *T'*.

FIG. 3.



If one blows hard enough through *CD* the liquid in *T* will be drawn up into the throat at *a*, where it will be broken up into spray.

THE DISK PARADOX.—A brass disk *DD* (Fig. 4) is soldered to the end of a tube *T*, and a light metal disk *dd* is held against *DD* by blowing strongly through *T'*. The region between the two

FIG. 4.

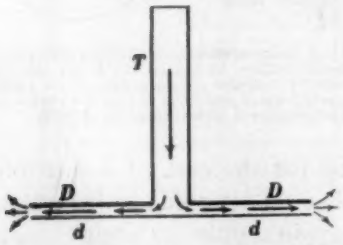
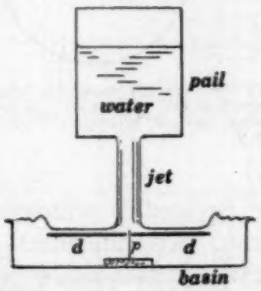


FIG 5.



disks is a region of high velocity, and as the stream comes out at the edge of the disks its velocity falls and its pressure rises, according to Bernoulli's principle. Therefore the pressure of the air in the region between the two disks is less than the pressure of the outside air, and consequently the outside air pressure holds the two disks together.

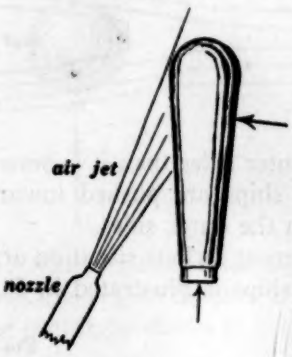
A complete hydraulic analogue of Fig. 4 is shown in Fig. 5.

A thin metal disk *dd* is kept from moving sidewise by a pin *p* which projects through a small hole in the disk, and the disk is held up by the jet of water! The jet spreads out over the disk as a thin layer of rapidly moving water, and when this flowing water reaches the edge of the disk it loses its velocity and raises itself to the higher level of the still water in the basin.

THE BALL AND AIR JET.—A small ball floats steadily in an air or steam jet, as shown in Fig. 6. The impact of the jet against the ball holds the ball up, and when the ball starts to fall out of the jet, as shown in Fig. 6, it is pushed back into the jet because the

FIG. 6.

FIG. 7.



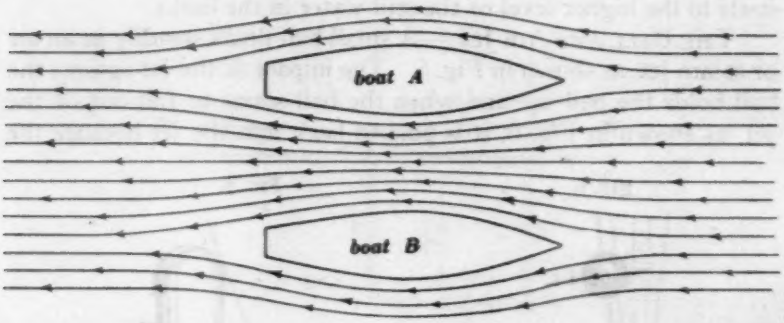
pressure of the surrounding still air is greater than the pressure of the rapidly moving air in the jet (Bernoulli's principle).

An ordinary file handle may be supported by an air jet, as shown in Fig. 7.

ATTRACTION OF TWO SHIPS STEAMING ALONG SIDE BY SIDE.—As a ship steams along through a body of still water, the water at a given point moves as the ship approaches, and comes to rest again when the ship is past. That is, the motion of the water is not what is called steady motion, and, therefore, Bernoulli's principle does not apply. But the dynamic effects associated with a ship steaming through a body of still water are exactly the same as the dynamic effects associated with a steady stream of water flowing past a ship which is standing still, and in the latter case the fluid motion is steady and Bernoulli's principle does apply. Thus Fig. 8 represents a stream of water flowing past two ships. The velocity of the water is greatest between the two boats where

the stream lines are most crowded. Indeed, the velocity of the water is greater between the boats than it is on the outer sides of the boats; therefore the level (pressure) of the water is greater

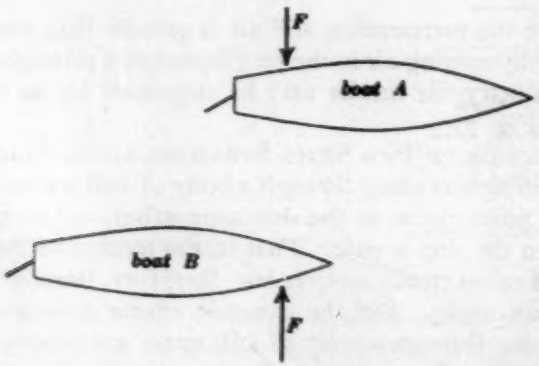
FIG. 8.



on the outer sides than it is between the boats; and consequently the two ships are pushed toward each other by the high-level water on the outer sides.

The most serious situation arising from the attraction of two moving ships is illustrated in Fig. 9. The forces *FF* in Fig. 9

FIG. 9.



tend to turn the ships, and these forces are apt to be much too large to be overcome by the action of either ship's rudder, even if the helmsmen are quick to set the rudders properly. Therefore ship *B* turns towards *A* and a collision results.

An experiment which illustrates the effects shown in Fig. 8 is to hang two smooth balls side by side, as shown in Fig. 10, with a space of about an inch between the balls; the balls are pulled together by blowing between them.

FIG. 10.

THE CURVED FLIGHT OF A SPINNING BALL.—To analyze the effect of the air upon a moving ball it is best to think of the ball as standing still with the air blowing past it, as shown in Fig. 12.

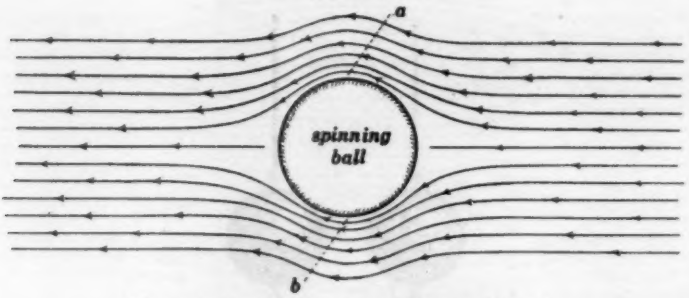
FIG. 11.

Air whirl produced near a spinning ball—air everywhere at rest except in so far as it is affected by the spinning ball.

Fig. 11 shows the air whirl near a spinning ball; and Fig. 12 shows a blast of air streaming past a ball that is not spinning. Let us consider a combination of Figs. 11 and 12,—that is, let us

consider how a blast of air streams past a spinning ball. At *a* the stream and the whirl both give a velocity from right to left, —that is, two causes are acting together at *a* to produce velocity from right to left. At *b*, on the other hand, the stream tends to

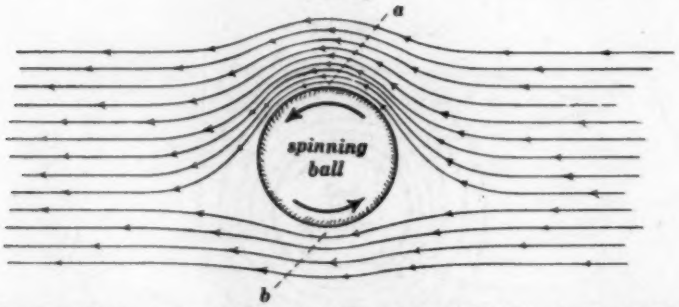
FIG. 12.



Air stream flowing past a ball which is not spinning.

produce a velocity from right to left, whereas the whirl tends to produce velocity from left to right,—that is, two causes act in opposition to each other at *b* to produce velocity. Therefore the velocity at *a* is much greater than the velocity at *b*, as shown in Fig. 13. Therefore, according to Bernoulli's principle, the

FIG. 13.



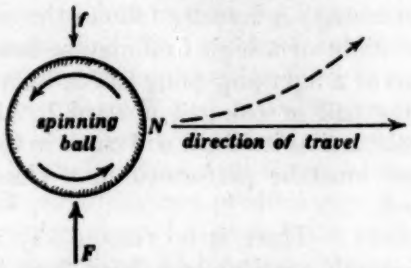
Air stream flowing past a spinning ball. The velocity is high at *a* and low at *b*; consequently the air pressure is high at *b* and low at *a*, thus producing the unequal forces *F* and *f* in Fig. 14.

pressure of the air at *b* is greater than the pressure of the air at *a*, and consequently the spinning ball is pushed upwards by the air stream or blast.

The dynamic effects in Fig. 13, where a blast of air blows from right to left past a spinning ball, are exactly the same as

the dynamic effects in Fig. 14, where a spinning ball moves from left to right through a body of still air. That is to say, the spinning ball in Fig. 14 is pushed upwards by the air, and therefore the ball travels in an upward curve, as indicated by the dotted curved arrow.

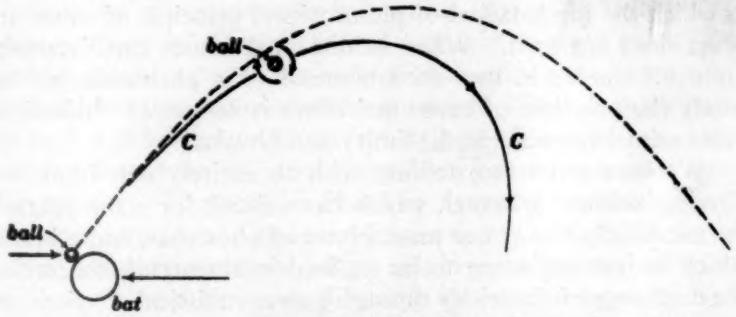
FIG. 14.



Unequal side forces *f* and *F* exerted on a spinning ball which is moving through the air.

Let us call the foremost point *N* of the travelling ball the *nose* of the ball. *The travelling ball curves in the direction in which the nose of the ball is moving because of the spin.* Thus, if the nose of the ball moves toward the right with respect to a

FIG. 15.



Curved flight of a high foul.

pitcher, the ball will curve to the right; if the nose of the ball moves upward (as shown in Fig. 14), the ball will curve upward, and so on.

Perhaps the best way to throw a curved ball for purposes of demonstration is to use a light ball of cork or pith and throw it from a pasteboard tube, moving the tube somewhat as one

would move a bat. The inside walls of the tube should be rough so that the ball will roll along the inside of the tube, and come out of the end of the tube with a rapid spinning motion.

Fig. 15 shows the curved flight of a high foul. The ball is set spinning rapidly as it glances off the bat, and instead of following the symmetrical dotted curve (which it would follow if it were not spinning) it actually follows the curve *CC*.

This curved flight of a high foul may be beautifully demonstrated by means of a light ping-pong ball or by means of an oak-gall. Throw the ball or oak-gall upward by the thumb as in shooting a marble, and as it falls it will curve in toward one's feet. This experiment must be performed in a closed room where there is no wind.

THE SPIT-BALL.—There is no reason why a sharp-pointed stick standing exactly vertical on a hard floor in a quiet room should fall one way more than another. Therefore the stick will not fall either way! That is good logic, but it is bad physics. The stick always does fall. The fact of the matter is that such a stick is unstable; and in the case of an ideally sharp stick standing perfectly vertical, an infinitesimal initial disturbance would be enough to start the fall in some direction, and then away she goes! We are here dealing with a kind of physical phenomenon in which the much-talked-of philosophical principle of cause and effect does not hold. When infinitesimal causes can determine finite differences in the ultimate trend of a phenomenon, then surely the principle of cause and effect is no more! Indeed, an infinitesimal cause is (in the limit) non-physical!

We here stand face to face with an entirely new branch of physical science, a branch which has existed for some years in the minds of some of our most advanced physicists, and a branch which is just beginning to be realized in researches concerning the discharge of electricity through gases: statistical physics. All correlations in this branch of physics must be sought for on the basis of statistical studies; the same thing never happens twice; and the old-fashioned idea of *cause and effect,* or the idea of *one-to-one correspondence,* or the idea of *law, in the sense of functional relationship* (as one may prefer to call it), gives place to chance and the laws of probability.

The older physics is sometimes called *macro-physics,* and the newer *micro-physics;* but this is distinctly misleading, because

the largest-scale phenomena with which we deal in this world of ours belong to statistical physics,—namely, weather phenomena. And the essential method in meteorology is the statistical method. Some little insight into atmospheric phenomena can be obtained by studying functional relationships, such as are expressed by Boyle's law of gases, the law of constant circulation in the vortex theory of fluid motion, the functional laws of radiation and absorption, and the functional relations of long-time and wide-space averages; but the thing which is now most needed in meteorology is the study and classification of storm types, the establishment of norms and probable departures therefrom, and, above all, the study of incipient stages of storm movements where very small variations may produce very large ultimate departures. If weather control is ever to be realized it must be by studying the possibilities of big consequences from small beginnings! Our Weather Bureau should employ, say, twenty of the most talented young men of highly-developed and rigorously-trained imaginative faculty, and set them to work studying storm data, averaging in time and space to discover norms, studying individual departures, and, above all, visualizing storm movements on a basis of the most minute study of details. No other method can ever lead to important results in meteorology.[2]

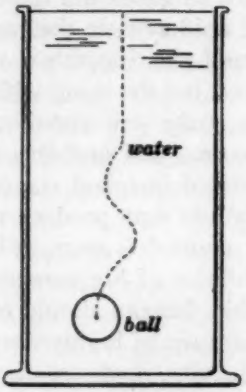
Consider a very smooth ball which is moving through still water without spinning. There is certainly no more reason why the ball should jump to the right than to the left. Therefore it must continue to move straight forward! That is good logic; but such a ball is no more subject to logic than is a sharp stick! The fact is that the ball does jump sidewise, and in a most irregular manner. This may be shown by dropping a smooth marble in a jar of still water. The marble goes nearly straight for several inches, and then suddenly jumps sidewise, as shown in Fig. 16. Similarly a smooth baseball jumps sidewise irregularly as it moves through the air, if the ball is not spinning.

Fig. 17 shows how a rapidly moving stream of air splits when it flows past a ball, and the dividing lines, or *vortex sheets, aa* and *bb* between moving and still air are unstable. The result is that the stream of air *aa* (or *bb*) spurts upward and downward in

[2] See a very brief article by W. S. Franklin in *Science*, vol. xiv, pp. 496, 497, September 27, 1901.

irregular succession. When the stream *aa* spurts downward it produces an upward force or reaction on the ball, and *vice versa*. That is to say, the irregularities of the streams *aa* and *bb* cause a series of irregular side forces to be exerted on the ball.

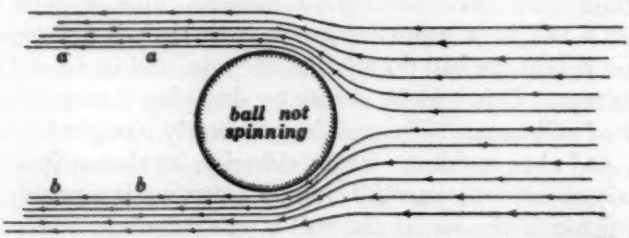
FIG. 16.



Irregular path of smooth ball (not spinning) as it sinks in water.

The dynamic effects associated with a ball standing in a stream of air as shown in Fig. 17 exist also when a ball moves through still air. Therefore if a ball moves fast enough through still air to produce unstable vortex sheets, the irregular sidewise

FIG. 17.



Showing how a rapid stream splits when it flows past a ball.

spurts of the air as it flows around behind the ball will cause the ball to travel in an irregular zigzag path.

The instability and consequent irregularity of a stream of rapidly-moving fluid is exemplified by the sensitive flame. Every one knows how an ordinary gas flame suddenly becomes turbu-

lent and produces a roaring sound when it is turned up too high (velocity of gas too great), and when a gas flame is on the verge of becoming turbulent the least disturbance is sometimes sufficient to throw the flame over into the turbulent form. A sensitive flame can easily be made by drawing out a glass tube to give a smooth nozzle about a millimetre in diameter and burning a jet of ordinary illuminating gas at this nozzle. When properly adjusted the flame responds to a hissing sound across a large room.

The hissing sound of a high-pressure steam jet is due primarily to an unstable condition of the jet near the nozzle, an unstable condition which is somewhat similar to the instability of the vortex sheets *aa* and *bb* in Fig. 17; and this instability leads to an excessively irregular and complicated whirling and eddying motion in the jet. Indeed, a jet of gas or steam is infinitely complicated! Every one concedes the idea of infinity which is based on abstract numerals—one, two, three, four, and so on *ad infinitum*—and the idea of infinity which is based on the notion of a straight line; but most men are concerned with more or less persistent or steady phases of the material world, their perception does not penetrate into the substratum of utterly confused and erratic action which underlies every physical phenomenon, and they balk at the suggestion that the phenomena of fluid motion, for example, are infinitely complicated and erratic. Surely the abstract idea of infinity is nothing as compared with the dreadful intimation of infinity that comes from things that are seen and felt. We are immersed in an illimitable sea of phenomena every element of which is infinitely complex, and every minute detail is essentially erratic.

Noiseless City Streets. ANON. (*Sci. Amer.*, cix, No. 15, 279.)—In Germany a cheap and ready method of asphalting a stone-paved street is in use which shows good results. The spaces between paving blocks are cleaned out to the depth of an inch and then a layer of melted asphalt is flowed over the street surface to a depth of about one inch. Before it is cooled, sand is sprinkled on, and the surface is smoothed. A section of this kind is laid in Frankfort and appears to stand the wear remarkably well. Should it show success generally it will be an excellent means of deadening the noise of street traffic at a small expense. The process is quickly carried out and repairs are easily made.

Crystallization of Steel. F. GIOLITTI. (*Acad. Sci. Torino, Atti,* xlviii, 10a, 413.)—The author describes experiments which lead him to take a somewhat different view from that of Belaiew as to what occurs during the crystallization of steel. He concludes that there are two successive processes of crystallization: (1) The formation of mixed crystals of the fused metallic mass, and (2) the segregation of the ferrite or cementite from the solid solution. Contrary to Belaiew's results, slow cooling favors the formation of Widmanstätten's figures in steel containing about 0.32 per cent. carbon and heated to 1000° C. for eight hours, while rapid cooling renders them less perfect. Belaiew's hypothesis to explain the formation of Widmanstätten's structure and his theory of secondary crystallizations are not accepted.

Applications of Positive Rays to the Study of Chemical Problems. J. J. THOMSON. (*Cambridge Phil. Soc. Proc.,* xvii, 201.)—Two samples of gases obtained from the residues of liquid air are examined. One sample, treated so as to contain the heavier gases, is found to contain xenon, krypton, and argon. There are no lines on the photograph unaccounted for, hence it is concluded that there are no unknown heavy gases in the atmosphere in quantities comparable with the known gases. The other sample, treated so as to contain the lighter gases, is found to contain helium, neon, and a new gas with the atomic weight 22. The relative brightness of the lines for this gas and for neon shows that the amount of the new gas is much smaller than that of neon. The new gas, of atomic weight 3, which this method of analysis has shown to be present in the tube under certain conditions, is also investigated. The gas had occurred sporadically in the tube from the time of the earliest experiments, but its appearance could not be controlled. After a long investigation into the source of this gas, it is found that it always occurs in the gases given out by metals when bombarded by cathode rays; a trace of helium is also usually found on the first bombardment. The metals used are iron, nickel, zinc, copper, lead, and platinum. The gas is also given off by calcium carbide. Various experiments illustrate the stability of the gas.

Liquid Aluminum. ANON. (*Amer. Mach.,* xxxix, 3, 106.)—According to the German press, aluminum has been successfully brought to a liquid condition, so that it may be spread, when cold, over any dry surface. The composition is applied like a paint with a brush, and looks like a dull silver coating. It is said to be an excellent preventative of rust, to be resistant to heat, elastic, durable, and resistant to atmospheric influence, and to be an excellent substitute for tin in plating.

PROPORTIONING OF LONG-SPAN TRUSS AND CANTILEVER BRIDGES.*

BY

JOSEPH MAYER,

Assistant Engineer, Quebec Bridge Commission, Montreal, Canada.

W_i^c in (61*a*) is the weight of steel of one cantilever arm with erection of the suspended span by building out from the ends of the two cantilever arms. The weight does not include the erection material required; it includes only the steel remaining in the completed bridge. The main pier posts required for the loads coming from the cantilever arm and one-half the cross bracing between these posts are included.

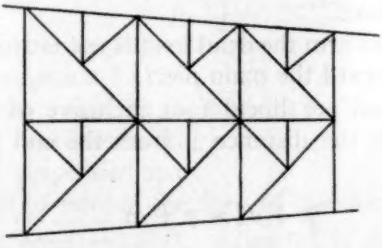
The other symbols in the formula (61*a*) are the same as in the formula (61), except that the h used in the calculation of A and B is here $h = 0.3804\, l_c$.

$$\tan \beta \text{ for the subdivided K system} = \frac{4l}{0.3804 l_c}$$

where l is the panel length and $2l$ the distance between succeeding main posts.

The subdivided K system is shown in Fig. 3.

FIG. 3.



The formulas (61) and (61*a*) are based on the assumption that the dead load per lineal foot of cantilever arm at its end is the same as the dead load per lineal foot of suspended span,

Continued from page 670, Vol. CLXXVI, No. 6.

which is always approximately the case, and that the dead load d_x per lineal foot of cantilever arm at the distance x from its end is

$$d_x = \frac{d + 3.5d}{l_c} \cdot x$$

where d is the dead load per foot at end of cantilever arm.

This is not exactly true, but the ratio $\frac{W_p}{W_i}$ is so nearly alike for uniform loads and for loads increasing toward the pier that a considerable error in the assumed increase of dead load toward the pier will not materially affect its value.

The foregoing method of finding the weights of the trusses required for meeting the dead and live load stresses from different sources as directly as possible keeps the weights of the steel required for the different forces separate and makes it possible to judge the influence of the various forces. The influence of a change in width or of a change in the weight of the floor can be easily calculated.

When only the total weight of steel is wanted, all the vertical loads can be bunched together and the weight of the steel required to meet their stresses can be found by one calculation if the loads are known.

In the calculation of the stress sheets for ordinary spans the usual method adopted is to guess the dead loads, calculate the stresses, the sections, and the resulting weights; then the dead load assumed is corrected and the calculation is repeated with the corrected dead load.

In a cantilever arm the dead load is not uniform, but increases from the end toward the main pier.

The total load per lineal foot inclusive of the moving and impact load μ at the distance x from the end of the cantilever arm is

$$\mu + d_x = p + qx \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (64)$$

In this equation $p = \mu + 0.97$ times the weight of the suspended span per lineal foot.

q is a constant which must first be guessed at. $q = \frac{2p}{lc}$ is a good first guess for very long spans.

The total weight of the cantilever arm and of its moving load is then

$$W = \int_0^{l_c} (p + qx)\, dx = pl_c + \frac{ql_c^2}{2}$$

or

$$q = \frac{2}{l_c^2}(W - pl_c) \times 0.97 \ldots\ldots\ldots\ldots\ldots\ldots \quad (65)$$

The factor 0.97 is introduced with the dead loads because these call for about 3 per cent. less weight in the trusses than an equal amount of moving and impact load μ.

The equivalent weight at the end of the cantilever arm is

$$\frac{pl_s}{2}.$$

With the assumed q, the weight of steel in the cantilever arm with parallel chords is found to be

$$W_p^c = W_{\mu + d_x} + F + W_\omega \ldots\ldots\ldots\ldots \quad (66)$$

In this equation

$$W_{\mu + d_x} = \frac{l_c}{24}\left[Al_c\left\{2p\,(3l_s + 2l_c) + ql_c^2\right\} + 4B\left\{3p\,(l_s + l_c) + ql_c^2\right\}\right] \ldots\ldots\ldots\ldots\ldots\ldots \quad (67)$$

A is given in equation (4).
B is in equations (12), (13), and (14).
l_c = length of cantilever arm.
l_s = length of suspended span.
F is the weight of steel in the floor of the cantilever arm.

W_ω is given in equation (53). After W_p^c is found the weight of timber, etc., in the floor and the moving load of the cantilever arm $= \mu l_c$ are added to obtain W, and with this the corrected q is obtained from equation (65).

With this the calculation of $W_{\mu + d_x}$ is repeated by equation (67).

Another weight W and another q is obtained which may be used for one more calculation.

For inclined chords when

$$h_x = a + bx \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (68)$$

where h_x is the height at the distance x from the end of the cantilever arm; with a load at the end of the cantilever arm equal to $\frac{pl_s}{2}$ and with a load per foot at the distance x from the end of the cantilever arm $= \mu + d_x = p + qx$, we obtain for the weight of the chords required to carry the vertical loads:

$$W_{i\ ch}^{\mu + d_x} = (g_c + g_t)\, K \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (69)$$

$$\text{where } g_c = \frac{3.4 a_c \sec^2 \delta_c}{2 U_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (70)$$

$$g_t = \frac{3.4 a_t \sec^2 \delta_t}{2 U_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (71)$$

$$K = \frac{1}{3}\left(\frac{q l_c^3}{3b} + \frac{(3bp - aq)\, l_c^2}{2b^2} + \frac{3pl_s - 3abp + aq^2}{b^4} \times 2.3026 a \log \frac{h_p}{a} \right) \quad \ldots\ldots\ldots\ldots\ldots \quad (72)$$

For the weight of the webs we find

$$W_{i\ web}^{\mu + d_x} = \frac{B}{6}\left\{ 3pl_c\,(l_s + l_c) + q l_c^3 - 3bK \right\} + \frac{3.4 a_{c_3} l_c \left\{ 3p\,(l_s + l_c) + q l_c^2 \right\} \tan \delta_t}{6 U_{c_3}} \quad \ldots\ldots \quad (73)$$

B is to be taken at a distance of about $\frac{1}{4} l_c$ from the main pier.

U_{c_3} = axial unit stress in the pier post.

h_p = height of truss at the main pier; $h_p = a + bl_c$; $a_{c_3} \sim 1.5$.

δ_t and δ_c are the angles of the tension and compression chords respectively with the horizontal.

For the weight of steel in the cantilever arm we obtain

$$W_i^c = F + W_\omega^1 + W_{i\ ch}^{\mu + d_x} + W_{i\ web}^{\mu + d_x} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (74)$$

After this weight is found the total weight of the cantilever arm and of its moving load is calculated and a corrected value of q determined with which the calculation is repeated.

CANTILEVER ARMS WITH CURVED CHORDS.

The foregoing formulas for the weight of steel of a cantilever arm only apply with straight chords.

With curved chords the fundamental formulas for the weight of the chords and the webs which apply generally to all trusses must be used.

Since the height and the angle β of the diagonals with the vertical change with every main panel, the general formulas must be used for each main panel in succession and the results added.

With horizontal bottom chords the laterals and the cross bracing can be calculated in one operation for the whole cantilever arm.

For the weight of parallel chords of one panel we have:

$$W_{p.\,ch} = M_a \cdot A = M_a \frac{3 \cdot 4}{h}\left(\frac{a_t}{U_t} + \frac{a_c}{U_c}\right)$$

where M_a is the moment area for the panel.

When the chords are inclined the chord stresses and the lengths of the chords are increased. If the angles of the chords with the horizontal are δ_c and δ_t, then the formula for the weight of the chords in the panel becomes

$$W_{i.\,ch} = M_a \frac{3 \cdot 4}{h}\left(\frac{a_t \sec^2 \delta_t}{U_t} + \frac{a_c \sec^2 \delta_c}{U_c}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (75)$$

Here h is the height at the centre of the main panel.

The moment area M_a is approximately equal to the moment at the centre of the panel length multiplied by the panel length.

When p is the total equivalent load per foot of suspended span and $p_x = p + q.x$ is the load per lineal foot at the distance x from the end of the cantilever arm, then the moment M_x at the distance x from the end of the cantilever arm is

$$M_x = \frac{p \cdot x\,(l_s + x)}{2} + \frac{qx^3}{6} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (76)$$

We have, therefore, for the weight of the chords of one panel

$$W_{i\,.\,ch} = \left\{ \frac{px\,(l_s + x)}{2} + \frac{qx^3}{6} \right\} \frac{3.4l}{h_x} \left\{ \frac{a_t \sec^2 \delta_t}{U_t} + \frac{a_c \sec^2 \delta_c}{U_c} \right\} \quad \ldots (77)$$

where h_x is the height at the centre of the main panel at the distance x from the end of the cantilever arm. For the weight of the web with parallel chords we have

$$W_{p\,.\,web} = S_a B$$

With inclined chords the chords carry a part of the shear, and the shear of the web is equal to the total shear, less the shear in the chords.

The total shear S at the distance x from the end of the cantilever arm is

$$S = p\left(\frac{l_s}{2} + x\right) + \frac{qx^2}{2} \quad \ldots\ldots\ldots\ldots (78)$$

The shear S_{ch} in the two chords is

$$S_{ch} = \left\{ \frac{px\,(l_s + x)}{2} + \frac{qx^3}{6} \right\} \frac{\tan \delta_t + \tan \delta_c}{h_x} \quad \ldots\ldots\ldots\ldots (79)$$

The web shear S_{web} is, therefore,

$$S_{web} = p\left(\frac{l_s}{2} + x\right) + \frac{qx^2}{2} - \left\{ \frac{px\,(l_s + x)}{2} + \frac{qx^3}{6} \right\} \frac{\tan \delta_t + \tan \delta_c}{hx} \quad \ldots\ldots\ldots\ldots\ldots\ldots (80)$$

The shear area of the web is

$$S^a_{web} = S_{web} \cdot l \quad \ldots\ldots\ldots\ldots\ldots (81)$$

where l is the length of the main panel.

The weight of the web is $W_{i\cdot web} = S_{web} \cdot lB \ldots\ldots\ldots (82)$

The weight of the laterals and the cross bracing is found by the formulas previously given for cantilever bridges with straight chords.

Formula (53) applies without change with straight horizontal bottom chords.

In other cases slight modifications for the length easily found will serve. After the weight of the steel in the cantilever arm has been obtained its total weight is easily found. The value of q, which was first guessed to be $q = \frac{2p}{l_c}$, is then found by formula (65), and the calculation may have to be repeated with the corrected q.

The formulas here given for the web of a panel of the cantilever arm include with each panel one-half the weight of the two limiting verticals, if such occur in the design, but they do not include that part of the pier post which is needed for the stress coming from the top chord of the cantilever arm.

The shear in the top chord at the main pier is

$$S_{pp} = \left\{ \frac{pl_c\,(l_s + l_c)}{2} + \frac{ql_c^3}{6} \right\} \frac{\tan \delta_t}{h_p}$$

The weight of this part of the pier post is approximately

$$W_{pp} = \frac{S_{pp}\, h_p \cdot 3.4 \times 1.5}{Uc_2}$$

The calculations by means of the foregoing formulas are so simple that it is easily practicable to calculate the weights for various lengths of the suspended span, panel lengths and heights and to find thus the most economical design of the main span.

The design of the anchor arm is quite similar to that of the cantilever arm, and similar formulas might be derived for its weight after that of the main span and the pier moment are known.

An anchor arm five-sixths as long as the cantilever arm weighs with the anchorage, for the longest spans, if made of the same material as the main span, about the same as the cantilever arm.

The weight of the shoes, if of the same material as the rest of the bridge, is about 3 per cent. as much.

From numerous calculations for designs of cantilever bridges with main spans of 1400 to 2000 feet the following results referring to the best general dimensions were obtained.

The most economical height at main piers fluctuates to both

sides and near one-sixth the length of the main span. It is also influenced by the panel length, the nature of the web system, and by the curvature of the chords. It increases with the panel length, and is larger with inclined posts and a double system of web members than with vertical posts or with a single system of inclined posts with numerous vertical subposts. It is also larger with the K system of web members than with the same moderate panel length and other web systems; it is more with curved than with straight chords. The best height at the main piers is largest with very long panels near the piers and with double intersection web with inclined posts and with curved chords as in the Forth Bridge. Such a panel length is, however, unsuitable for shop manufacture and erection by means of an erection traveller.

Both the published designs for the new Quebec bridge are too high at the piers for the best economy of weight. Their great height was chosen to reduce the required cross section of the heaviest bottom chords. The influence of the height at the main pier on the economy of weight is very small so long as the deviation from the most economical height does not exceed about 5 per cent.

A small height at the end of the cantilever arm is economical for its weight. The best average panel length in feet for very long double-track spans is

$$\frac{4L}{300} + 27,$$

where L is the length of the main span in feet.

PRIMARY UNIT STRESSES.

It is a common practice to prescribe for ordinary spans a certain unit stress, differing for compression and tension members, for the sum of dead + live + impact stress and another unit stress 25 per cent. larger for dead + live + impact + wind stress. This gives in different members unit stresses varying by 25 per cent., according to the proportion of the wind stress.

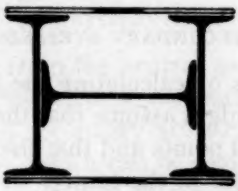
A scientific design calls for a uniform factor of safety and a uniform unit stress in members of the same nature. This result is only secured by determining the sections by dividing the sum of all the axial compression by a permissible axial unit stress obtained

from a total unit stress for compression, reduced for length of member in long members, and for bending stress due to weight of member.

Recent tests show for full-sized compression members made of two channels latticed on the two open sides smaller ultimate strength than was previously often assumed. They have also shown that H sections composed of three built or rolled I beams, with the open sides latticed, are about 15 per cent. or more stronger than the former sections. It would, therefore, be reasonable to use 15 per cent. more unit stress in the latter than in the former sections.

Full-sized eyebars are about 10 per cent. stronger than riveted tension members: larger unit stresses in the former than in the latter are, therefore, justified.

FIG. 4.



These facts were kept in mind in the selection of the unit stresses for the examples given. The writer would adopt for all bridges of carbon steel 20,000 pounds tension per square inch for the sum of all axial stresses in eyebars.

18,000 pounds in riveted tension members.

14,000 pounds per square inch gross in short struts made of two channels latticed.

$$17{,}500 - 70\,\frac{l}{r}$$

in long ones and 15 per cent. more in struts made of 3 I beams latticed at the open sides, as in Fig. 4.

From these unit stresses for compression members, for the sum of all the stresses, the bending stress due to weight of member should be subtracted to obtain the proper axial unit stress.

These unit stresses should only be used for determining the sections where the secondary stress is not more than one-third of the primary stress.

Theoretical considerations, and the experiments with eyebars after Mr. Theodore Cooper and Colonel Howard led to the conviction that the ultimate strength of all tension members and the practical elastic limit of slender tension members are not affected by the amount of the coexisting cross bending produced by their own weight. To confirm this theory, the Board of Engineers of the Quebec Bridge had identical bars pulled apart while their weight was counterbalanced at numerous points, and while they were so cross-loaded as to produce equal bending moments as the weights of the longest bars when in the bridge. The tests showed that the ultimate strength and the elastic limit were not reduced by the cross-loading. For this reason the bending stresses due to the weight of tension members were neglected in all the foregoing calculations, while they were considered in all the compression members.

SECONDARY STRESSES.

The usual methods of calculating the stresses of riveted and pin-connected truss bridges assume that there are perfect frictionless hinges at the panel points and that the centre lines of gravity of all the members meet in the centres of these hinges. If such hinges and centric connections did exist, loads applied at the panel point would produce only axial tensions and compressions in the truss members.

The weights of the individual members would, however, produce bending stresses in them. These axial and bending stresses which would exist if there were perfect hinges at the panel points are called primary stresses. The absence of perfect hinges has three effects. It vitiates the calculation of the axial primary stresses. It greatly modifies the bending stresses due to weight of member, and it introduces additional bending stresses, called secondary stresses. If these secondary stresses are large the primary axial stresses of some of the minor truss members are changed considerably, but no short and accurate method of calculating these changes exists. The bending stresses due to weight of member which result from the absence of perfect hinges can be easily calculated, and it is best to calculate these modified bending stresses due to weight of member and to consider them

as the primary bending stresses. They are the only stresses which can be accurately calculated.

We are obliged to use the axial primary stresses as if they did really exist, since they are the closest approximation to the really existing axial stresses which we can obtain. By use of the best available methods for reducing those secondary stresses which coexist with the maximum primary stresses the errors in these most important primary stresses can be kept within narrow limits.

Large secondary stresses coexisting with the maximum primary stresses greatly increase the maximum total stresses and they make it impossible to calculate these maximum total stresses with the desirable accuracy. They should, therefore, be avoided wherever this is possible.

The size of the secondary stresses greatly depends in cantilever and anchor arms on the curvature of the chords, and in all bridges on the kind of web system used, and on the ratio of $\frac{e}{l}$ where e is the distance from the neutral axis of a member to the extreme fibres of its cross section, measured in the plane of the truss. To obtain small secondary stresses this ratio should be less than one-eighteenth, which can be easily accomplished.

If the lengths of the members of a riveted span are so chosen that the continuous straight chords and the web members have their panel points in straight lines for full live load, and if the connections are so designed that with this loading the end bending moments in the web members are o, then the secondary stresses due to vertical loads occur during erection and are o with full live load. This requires the use of drift pins to force the members into position during erection, and is for this reason, in ordinary spans where the secondary stresses are small, generally avoided.

If pin-connected spans are erected with lubricated pins and swung free from the scaffolding before riveting up the top chord splices, and if the lengths of the members give the geometrical shape of the truss, assumed in the design of the splices, under dead load stresses, then there arise no secondary stresses from dead load. Those from moving load, wind stresses and differences of temperature are in ordinary spans moderate and are in them generally neglected.

Quite considerable secondary stresses arise from differences

of temperature of different parts of the same compression member when some are in the shade and some in the sun.

The sum of all the secondary stresses in fully stressed riveted chords of well-designed ordinary spans, coexisting with maximum primary stresses, seldom much exceeds one-third of the primary stresses. In eyebar chords and in slender diagonals with a small ratio of $\frac{e}{l}$ the secondary stresses are smaller.

In vertical posts with the floor beams riveted to them the sum of the secondary stresses often much exceeds one-third the sum of the coexisting maximum primary stresses. If secondary stresses are not otherwise considered it would be desirable to reduce the primary unit stresses in these posts to about three-fourths of those in compression chords with the same ratio of $\frac{l}{r}$. These posts very often have surplus sections. The fact that they are safe in spite of a very large percentage of secondary stress does. therefore, not prove that fully-stressed members would be equally safe with the same ratio of secondary stresses.

In ordinary spans it is common practice to neglect the secondary stresses, and experience shows that they are safe with the unit stresses in common use, say those of the American Railway Engineering Association.

This shows that the steel at present in use can safely carry the usual primary stress plus secondary stress amounting to about one-third as much.

If the bridges of unusual or unprecedented dimensions are so designed with the common primary unit stresses that the sum of all the secondary stresses does nowhere exceed one-third of the coexisting maximum primary stresses they will be safe.

There is no good reason for taking larger unit stresses in long than in short spans, provided that in both the moving load and wind pressure assumed are equal to the largest actual loads which will ever come on the bridge, and provided that the impact and secondary stresses are correctly calculated for both.

The neglect of the secondary stresses in long spans is only justified if it can be proven that they are no larger, compared with the coexisting maximum primary stresses, than in spans of ordinary dimensions which have been proven safe by past experience. The only way to prove this is to calculate the secondary

stresses wherever there is reason to believe that they may exceed one-third the maximum coexisting primary stresses. Where such excess occurs the sections should be increased until the total stress does not exceed by more than one-third the permissible primary unit stress.

Unless special measures are taken to prevent it, several features of long-span cantilever bridges largely increase the secondary stresses.

First.—The long and comparatively shallow floor beams of very long spans cause by their deflection, if riveted to the posts, much larger secondary stresses in them than the shorter, relatively deep floor beams of short spans.

Second.—In very long spans the main posts are made of four webs, and they are very broad, measured in the direction of the floor beams. This also increases their secondary stresses arising from the deflection of the floor beams.

Both these facts result in large end moments of the floor beams requiring special end connections to provide for them. In many cases hinged connections of the floor beams to the posts are the only effective remedy for excessive secondary stress from these causes.

Third.—The four webs of the posts and the chords largely increase their secondary stresses arising from wind stresses and from difference of temperature of the parts in the sun and those in the shade.

Fourth.—Unless all the truss members of cantilever bridges are hinged to the main shoes, large secondary stresses arise at the shoes in the truss members.

Fifth.—If the suspended span is carried by eyebar hangers extending from the ends of its bottom chords to the ends of the top chords of the cantilever arms large secondary stresses arise in them from changes of temperature and moving load.

Sixth.—The large dimensions of the bottom chords of the cantilever and anchor arms result, if they are supported at every panel point, in a large ratio of $\frac{e}{l}$ and consequently in large secondary stresses.

The measures taken to reduce excessive secondary stresses coexisting with maximum primary stresses are as follows:

First.—The lengths of all the truss members are so chosen

that the trusses have their geometrical shape assumed in the design of the chord and post splices and of the riveted connections, when the main span is fully loaded, which gives maximum chord stresses with small coexisting secondary stresses from vertical loads.

Second.—The pins are lubricated with graphite so that the members adjust themselves, at least from the time of putting them into place to the completion of the erection, thereby reducing the secondary stresses due to pin friction.

Third.—All the truss members are hinged at the main shoes by means of large pins and thimbles or sleeves to reduce the unit pressures and to facilitate the adjustments, which is here of special importance

Fourth.—Such thimbles, here of manganese bronze, are also used between the pins and the holes of the eyebar suspenders carrying the suspended span.

Fifth.—The floor beams when riveted to the posts have their end connections so designed that their end moments are o for dead load plus one-half. This reduces the bending moment in the posts, from the deflection of the floor beams, to less than half that with the usual design.

Sixth.—Where this bending moment would still produce too large secondary stresses in the posts, the floor beams are connected to them by hinges.

Seventh.—Where the bottom chord sections of the cantilever and anchor arms are large the chords are held only at every second panel, thus reducing the ratio $\frac{e}{l}$ and still more the resulting secondary stresses. By these measures it is practicable to reduce the secondary stresses in all but a few members to less than one-third the coexisting maximum primary stresses. Where this is impossible the sections should be increased by the proper amounts.

If the secondary stresses are not thus provided for, many of them which would not recur after a single overstraining of the metal beyond its elastic limit are probably practically harmless, but those caused by alternating stresses overstraining the metal alternately in opposite directions would probably shorten the life of the bridge and might even endanger its safety.

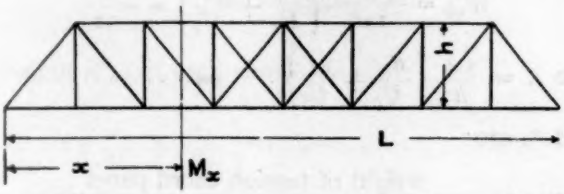
The only certainly safe course is, therefore, to provide additional sections at least for those secondary stresses which exceed the coexisting maximum primary stresses by more than one-third.

APPENDIX A.

DERIVATION OF FORMULAS FOR ORDINARY TRUSSES.

Let us consider a bridge truss with parallel chords (see Fig. 5) acted upon by a uniform moving load equal unity per lineal foot

FIG. 5.



of truss. All the chord stresses are maxima when the bridge is fully loaded. The end reaction is $\frac{L}{2}$ and the moment at distance x from the end of the span is

$$Mx = \frac{L}{2}\,x - \frac{x^2}{2} = x\,\frac{(L-x)}{2}$$

The chord stress at panel points is

$$\frac{Mx}{h} = \frac{x\,(L-x)}{2h}$$

The area of the compression chord is approximately $\frac{x\,(L-x)}{2\,hU_c}$; that of the tension chord $\frac{x\,(L-x)}{2\,hU_t}$ where U_c and U_t are the axial unit stresses for compression and tension respectively. In bridges with long panels the bending stresses per square inch in compression members due to their weight are important and must be subtracted from the permissible total unit stress. The weight of the compression chord is approximately

$$W^c_{ch} = \int_o^L \frac{3.4a_c}{2hU_c}\,x\,(L-x)\,dx$$

or

$$W^c_{ch} = \frac{3.4a_c\,L^3}{12hU_c}$$

The weight of the tension chord is

$$W_{ch}^{t} = \frac{3.4 a_t L^3}{12 h U_t}$$

and the weight of both chords is

$$W_{ch} = \frac{3.4 L^3}{12h}\left\{\frac{a_c}{U_c} + \frac{a_t}{U_t}\right\} = \frac{AL^3}{12}$$

Where $A = \frac{3.4}{h}\left\{\frac{a_c}{U_c} + \frac{a_t}{U_t}\right\}$ ..... (4)

a_c and a_t are:

$$a_t = \frac{\text{weight of tension chord panel}}{3.4 \times \text{its required net area in square inches} \times \text{length in feet}}$$

$$a_c = \frac{\text{weight of compression chord panel}}{3.4 \times \text{its required gross area in square inches} \times \text{length in feet}}$$

h and L are given in Fig. 5

Another instructive method of obtaining this formula is as follows: The moment at distance x from the end of the span is

$$M_x = \frac{x(L-x)}{2}$$

If the moments are entered as ordinates to the corresponding values of x as abscissæ we obtain a moment curve, and between it and the axis of abscissæ a moment area.

An element of this area is

$$\frac{x(L-x)}{2}\,dx$$

The whole area is

$$M_L^a = \int_0^L \frac{x(L-x)}{2}\,dx = \frac{L^3}{12}$$

The average moment or the average ordinate of the moment curve is $\frac{L^2}{12}$. The average chord stress for a uniform height h is $\frac{L^2}{12h}$.

The average compression chord section is $\frac{L^2}{12hU_c}$

The weight of the comparison chord is, therefore,

$$W_{ch}^c = \frac{3{\cdot}4L^3a_c}{12hU_c}$$

and the weight W_{ch} of both chords is

$$W_{ch} = \frac{3{\cdot}4L^3a_c}{12h}\left\{\frac{a_c}{U_c} + \frac{a_i}{U_i}\right\} \text{ as above} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4a)$$

This derivation shows that the weight of the chord is obtained by multiplying the moment area by

$$\frac{3{\cdot}4}{h}\left\{\frac{a_c}{U_c} + \frac{a_i}{U_i}\right\} = A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

The moment area used in the formula is that of the loads shown by the parabola of Fig. 6.

The actual moments determining the top chord sections of each half of the truss are given by the polygon $b_1b^1cc^1dd^1ee_1b_1$.

The moment area used in the formula for the weight of the chords is that between the parabolic arc shown and the axis of x.

In Fig 6,
$$\begin{cases} \text{the triangle } edd^1 = \frac{L}{16}\cdot\frac{1}{16}ee_1, \\ \text{the triangle } dcc^1 = \frac{L}{16}\cdot\frac{3}{16}ee_1, \\ \text{the triangle } cbb^1 = \frac{L}{16}\cdot\frac{5}{16}ee_1, \\ \text{the triangle } bb_1a = \frac{L}{16}\cdot\frac{7}{16}ee_1. \end{cases}$$

The correct moment area of the top chord of each half span is that of the parabola + the triangles

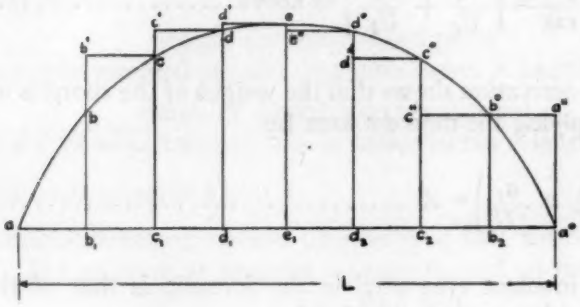
$$edd^1 + dcc^1 + cbb^1 - bb_1a = \frac{L}{16}\times\frac{1}{8}ee_1.$$

The area of the polygon representing the correct moment area of the whole top chord is, therefore, equal to the area used in the formula $+\frac{L}{64}ee_1$. The area of the parabola is two-thirds Lee_1.

The actual area is, therefore, nearly 2.35 per cent. larger than the area used in the formula.

The polygon in the right-hand half of Fig. 2 gives the actual moment area for the bottom chord. This is over 2.35 per cent.

FIG. 6.



smaller than the area used in the formula. The error made in the sum of the weights of the two chords by using the formula above given is ½ per cent. the result found by the formula being ½ per cent. too small. With more panels the percentage of error is smaller. The size of the error for other systems of web members can be easily ascertained in a similar manner. It is never large enough to affect the argument.

The shear at the distance x from the end of the span with this distance x loaded with unit load per foot of truss is

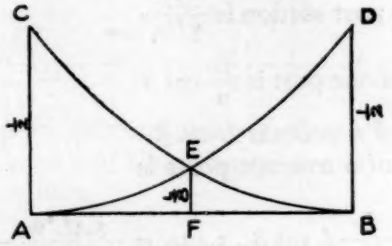
$$Sx = \frac{x^2}{2L}$$

The total shear area when x increases from o to L is

$$S_L^a = \int_o^L \frac{x^2}{2L} = \frac{L^2}{6}$$

The same area is obtained when the train moves in the opposite direction. The total shear area for both directions of motion is, therefore, $\frac{L^2}{3}$. The area $AEBA = \frac{L^2}{24}$ (see Fig. 7) gives the negative shears included in $\frac{L^2}{3}$.

FIG. 7.



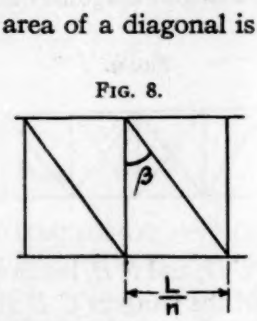
The positive shear area is $ACEDBA = \frac{7}{24} L^2$.

Taking both positive and negative shears, we obtain $\frac{L}{3}$ as the average shear from a unit moving load.

The average stress in the web diagonals is $\frac{L}{3} \sec \beta$. The sum of the lengths of all the diagonals for n panels is $L \operatorname{cosec} \beta$.

The average net area of a diagonal is $\frac{L \sec \beta}{3 U_t}$.

FIG. 8.



The weight of the diagonals is

$$W_d = \frac{3.4 L^2 a_{t_1} \sec \beta \operatorname{cosec} \beta}{3 U_{t_1}} = \frac{2 \times 3.4 L^2 a_{t_1}}{3 U_{t_1} \sin 2\beta}$$

Where U_{t_1} is the axial unit stress of the diagonals per square inch of net section and

$$a_{t_1} = \frac{\text{weight of diagonal}}{3.4 \text{ net section required in square inches} \times \text{length in feet.}}$$

The average shear is $\frac{L}{3}$; this is also the average vertical post stress.

The average post section is $\frac{L}{3U_{c_1}}$

The length of one post is $\frac{L}{n} \cot \beta$

The length of n posts is $L \cot \beta$.

The weight of n average posts is

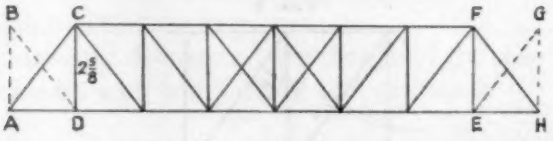
$$\frac{L}{3U_{c_1}} L \cot \beta \cdot 3.4 a_{c_1} = \frac{3.4 L^2 a_{c_1}}{3U_{c_1} \tan \beta}$$

The weight of the diagonals and counters of n panels and of n average posts is

$$\frac{3.4L^2}{3} \left\{ \frac{2a_{t_1}}{U_{t_1} \sin 2\beta} + \frac{a_{c_1}}{U_{c_1} \tan \beta} \right\}$$

The formula gives the weight of all the diagonals of Fig. 9 inclusive of the two dotted end diagonals and of the posts of the

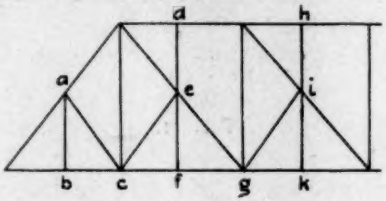
FIG. 9.



truss plus 3 posts *A B*, *C D*, and *F E*, but does not include the end posts *A C* and *F H* and the hangers *C D* and *F E* of the actual truss. The members included in the formula do not entirely cover the member omitted. To obtain good floor-beam connections and a satisfactory $\frac{l}{r}$ for the posts near the centre of the span, these latter have in short spans a large surplus of section.

In long spans (see Fig. 10), where the main diagonals go over two panels, the sub-posts *ac, ce, gi, ed, hi,* etc., and the sub-hangers *ab, ef, ik,* are not included in the formula.

FIG. 10.



To allow for these deficiencies the coefficient in front must be increased from 3.4 to 4 to obtain approximately correct results.

The formula is then

$$W_{web} = \frac{4}{3} L^2 \left\{ \frac{2a_{t_1}}{U_{t_1} \sin 2\beta} + \frac{a_{c_1}}{U_{c_1} \tan \beta} \right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12a)$$

The formula is approximate for uniform unit compressions in all the posts and uniform unit tension in all the diagonals. The formula must otherwise be used with the average unit stress in the tension members and the average unit stress in the compression members.

It shows that the weight of the diagonals is a minimum for $\beta = 45°$ and the weight of the posts for the longest panels.

$$\text{If } B_v = 4 \left\{ \frac{2\alpha_{t_1}}{U_{t_1} \sin 2\beta} + \frac{a_{c_1}}{U_{c_1} \tan \beta} \right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

we have

$$W_{web} = B_v \frac{L^2}{3},$$

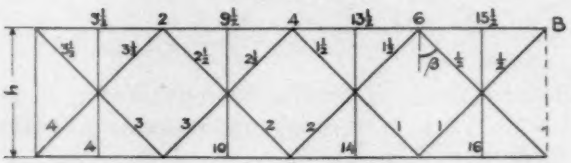
or the weight of the web is equal to B_v multiplied by the shear area.

Especially for deck bridges with the floor beams resting on the top chords, single web systems with inclined posts (Warren trusses) for short and double web systems with inclined posts for long spans are most economical in weight and give a good design, especially with the floor beams resting on the top chords. It is, therefore, of interest to obtain the formulas for the weights of such trusses.

The stresses in the chords are maxima for full load. Fig. 11 shows one-half of a truss with 16 panels. For a unit load per foot of truss the panel load is $\frac{L}{16}$. The chord stresses are obtained by multiplying the figures given on the chord panels by

$$\frac{L}{16} \cdot \frac{L}{8h}.$$

FIG. 11.



The weight of the top chords is, therefore,

$$\frac{2L^2 3.4}{128h}\left\{3\tfrac{1}{2} + 9\tfrac{1}{2} + 13\tfrac{1}{2} + 15\tfrac{1}{2}\right\}\frac{L}{8} \cdot \frac{a_c}{U_c}$$

$$W^c_{ch} = \frac{3.4 \times 42 a_c L^3}{512 h U_c} = \frac{3.4 L^3 a_c}{12.19 h U_c}$$

The weight of the tension chords is

$$W^t_{ch} = \frac{3.4 L^3 \times 44 a_t}{512 h U_t} = \frac{3.4 L^3 a_t}{11.64 h U_t}$$

The previously given formula for both chords is

$$W_{ch} = \frac{3.4 L^3}{12h}\left\{\frac{a_c}{U_c} + \frac{a_t}{U_t}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4a)$$

The error made by using this previously given formula for the sum of the weights of the tension and compression chord is but a small fraction of 1 per cent.

The average shear in the web is $\frac{L}{3}$ from the moving load of unity per foot of truss.

The average diagonal stress is $\frac{L}{6}\sec\beta$.

The average section of a tension web member is $\frac{L}{6}\frac{\sec\beta}{U_{t_1}}$; that of a compression web member $\frac{L}{6}\frac{\sec\beta}{U_{c_1}}$.

The sum of the lengths of all tension or all compression members is L cosec β.

The weight of the inclined web members is

$$\frac{\sec\beta \operatorname{cosec}\beta L^2}{6}\left(\frac{a_{c_1}}{U_{c_1}}+\frac{a_{t_1}}{U_{t_1}}\right)3{\cdot}4=\frac{3{\cdot}4L^2}{3\sin 2\beta}\left(\frac{a_{c_1}}{U_{c_1}}+\frac{a_{t_1}}{U_{t_1}}\right)$$

This does not include the vertical sub-posts and the vertical end posts. Allowing for these posts the formula becomes

$$W_{web}=\frac{4{\cdot}25}{3\sin 2\beta}\left\{\frac{a_{c_1}}{U_{c_1}}+\frac{a_{t_1}}{U_{t_1}}\right\}$$

for unit moving load per truss.

The average value of U_{c_1}, must be taken to obtain approximately correct results.

$$\text{If } B_i=\frac{4{\cdot}25}{\sin 2\beta}\left(\frac{a_{c_1}}{U_{c_1}}+\frac{a_{t_1}}{U_{t_1}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\text{Then } W_{web}=B_i\frac{L^2}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13a)$$

or the weight of the web is B_i multiplied by the shear area.

For the K system of web members we find in a similar manner

$$W_{web}=B_k\cdot\frac{L^2}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14a)$$

$$\text{Where } B_k=3{\cdot}75\left\{\frac{a_{t_1}}{U_{t_1}}+\frac{a_{c_1}}{U_{c_1}}\right\}\left\{\frac{1}{\sin 2\beta}+\frac{1}{2\tan\beta}\right\} \quad \ldots\ldots \quad (14)$$

The formula for the weight of the chords is the same as for the other web systems.

LATERAL SYSTEMS.

The two lateral systems are trusses with parallel chords and vertical end posts. The breadth B_r of the bridge is the height of the lateral trusses. The wind acts in both directions normal to the bridge. The wind stresses are, therefore all $\pm$. In the top

chords of the vertical trusses the compressions from the wind pressure are important; in the bottom chords the tensions. Each of the two chords of the top lateral system is at different times a compression chord. Those of the bottom lateral system are each at different times tension chords. From the formula for the weight of the chords of a truss with parallel chords we directly obtain the weight of the four chords of the two lateral systems for wind pressures p_w^c and p_w^t per foot of top and bottom lateral truss respectively.

$$W_{l\cdot ch} = \frac{3\cdot 4 l^3}{6\, B_r} \cdot \left(\frac{a_c}{U_c} \cdot p_w^c + \frac{a_t}{U_t} \cdot p_w^t \right)$$

$$\text{If } A_l = \frac{3\cdot 4}{B_r} \left(\frac{a_c}{U_c} \cdot p_w^c + \frac{a_t}{U_t} \cdot p_w^t \right)$$

$$\text{Then } W_{l\cdot ch} = A_l \cdot \frac{L^3}{6}$$

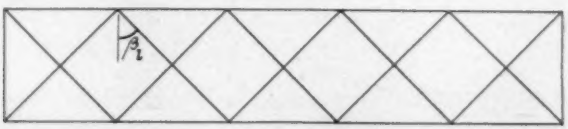
Or the weight of the lateral chords is equal to A_l multiplied by twice the moment area for one direction of wind normal to the bridge.

LATERAL WEB MEMBERS.

For long spans the lateral diagonals are commonly compression members of box section consisting of four or eight angles latticed on four sides.

Double system inclined web members like Fig. 12 are commonly used.

FIG. 12.



If there are cross struts they belong to the cross bracing and will there be included. All members have equal and opposite stresses, but the two opposite maxima but seldom occur, and never in rapid succession. The sections are, therefore, commonly and properly determined by calculating the section required for each of the two opposite stresses and taking the larger section

thus obtained. To allow for surplus sections near the centre of the span, I shall assume, in the derivation of the formula for the weights of the web members, that the average shear from a unit wind pressure per foot is $\frac{L}{3}$. The average stress in the lateral diagonals is then $\frac{L}{6}\sec\beta$. The sum of the lengths of all the lateral diagonals of one system is $L\operatorname{cosec}\beta_l$. The weight of one system is then

$$3{\cdot}4\,\frac{L^2}{6}\cdot\frac{\sec\beta_l\cdot\operatorname{cosec}\beta_l}{U_l}\cdot a_l=\frac{3{\cdot}4\,L^2a_l}{3U_l\sin 2\beta_l}$$

and the weight of the diagonals of the two lateral systems to resist a total lateral pressure p_w per foot of bridge is

$$W_{ld}=\frac{6.8p_wL^2a_l}{3U_l\sin 2\beta_l}\cdot$$

If

$$B_l=\frac{6.8p_wa_l}{U_l\sin 2\beta_l}$$

then

$$W_{ld}=B_l\frac{L^2}{3}$$

The total weight of the lateral systems inclusive of the lateral chords is, therefore,

$$W_l=W_{lch}+W_{ld}$$

$$W_l=\frac{3{\cdot}4L^3}{6B_r}\left(\frac{a_cp_w^c}{U_c}+\frac{a_lp_w^l}{U_l}\right)+\frac{6.8p_wL^2a_l}{3U_l\sin 2\beta_l}$$

or

$$W_l=A_l\frac{L^3}{6}+B_l\frac{L^2}{3}$$

The cross bracing is introduced partly to carry the wind pressures down to the end shoes, partly to give to the posts of the vertical trusses intermediate supports to reduce their unsupported length. Its total weight, inclusive of struts, diagonals, and

chords, will vary considerably with different designers. A liberal system can be provided with a weight $W_{cb} = 2W_{ld}$.

DEAD LOAD STRESSES.

The steel required to carry the moving loads, wind pressures, and the floor must itself be carried. The weight of this is in an ordinary span fairly uniformly distributed over the length of the span. The stresses in the chords are the same as those due to an equal slowly moving load per foot of bridge. The formula (4a), therefore, applies without change, also, for dead loads.

The average shear due to a dead load equal unity per foot is $\frac{L}{4}$, while that due to an equal moving load is $\frac{L}{3}$.

The impact in the floor-beam hangers and the sub-posts and sub-diagonals is more than in the main members, and these members have, due to engine loads, much larger stresses from the actual moving load than from the uniform moving load which is equivalent for the chords. These excesses were allowed for in the coefficients for B. The web members required for a unit dead load weigh, therefore, only 0.7 as much as those for a unit of slowly moving load, and the weight of the whole truss is only 83 per cent. as large to carry a unit dead load as for a unit of a slowly-moving load.

Formulas (4a), (12a), (13a), and (14a) give the weight of steel in a truss to carry a unit of a slowly-moving load. The weight to carry the load $\mu = m_r(1 + I) + m_h$ is

$$W_\mu = \mu L^2 \left(\frac{AL}{12} + \frac{B}{3} \right) = L \left(\frac{A\mu L^2}{12} + \frac{B\mu L}{3} \right)$$

If $C_\mu = \frac{AL}{12} + \frac{B}{3}$, we have

$W_\mu = \mu C_\mu L^2$ = total weight of truss required for the moving load stresses produced by the slowly-moving load μ.

The load μ per lineal foot of bridge replaces the actual rapidly-moving railroad load and its impact as well as the highway load.

$\omega_\mu = \mu C_\mu L$ is the weight per foot of bridge of the truss required for the moving load stresses of the load μ per foot of bridge.

The weight of steel in the trusses required to carry the dead load ω_μ per foot of bridge is 0.83 $\omega_\mu C_\mu L^2$; and the corresponding weight per foot of bridge is 0.83 $\omega_\mu C_\mu L$.

If 0.83 $C_\mu = C_d$, then the weight of steel per foot of bridge required to carry the dead load ω_μ per foot is

$$\omega_\mu C_d L, \text{ or } \mu C_\mu C_d L^2 = \omega_d$$

The dead load ω_d per foot of bridge must also be carried. The weight of steel per foot in the trusses to carry it is

$$\omega_d C_d L = \mu C_\mu C_d^2 L^3$$

The total weight of steel per foot required to carry the moving load μ and the consequent dead loads is, therefore,

$$\omega_\mu + d = \mu C_\mu L \{1 + C_d L + (C_d L^2) + \ldots\ldots\}$$

The infinite series in the bracket is convergent for $C_d L < 1$. In this case its sum is $\frac{1}{1 - C_d L}$, and we obtain

$$\omega_\mu + d = \frac{\mu C_\mu L}{1 - C_d L}$$

and the total weight of the truss required for the moving load μ is

$$W_{\mu + d} = \frac{\mu C_\mu L^2}{1 - C_d L}$$

In this formula the numerator gives the total weight of steel in the trusses required to meet the moving-load stresses, and the whole fraction gives the weight of steel in the trusses for both the moving-load and the consequent dead-load stresses.

When the first load, like the weight of the floor, is a uniform dead load d per lineal foot of bridge, then the formula for the weight of the trusses to carry it is

$$W_d = \frac{d C_d L^2}{1 - C_d L} = \frac{D C_d L}{1 - C_d L}$$

where D is the total weight to be carried.

For spans over 200 feet curved top chords in through bridges and curved bottom chords in deck bridges are preferable, because considerably more economical. Empirical formulas for their weight have been given in the text of the paper.

APPENDIX B.

WEIGHTS OF CANTILEVER BRIDGES.

When the suspended span is separately erected and floated into position it weighs as much as an ordinary span of the same length and width.

Formulas for its weight have been previously given.

When it is erected by building out from the ends of the two cantilever arms it is built with parallel chords, and the bottom chords in all but the centre panels are made rigid compression members and the top chord splices are designed for tension. This calls for an increase of a_t and a_c.

Additional members are required above the end posts. The resulting increases in weight can be easily estimated and added to the weight of an ordinary independent span with parallel chords, and for long spans of exceptional width.

WEIGHTS OF CANTILEVER ARMS.

Assuming first parallel chords, we have for the moment from unit moving load per foot at the distance x from the end of the cantilever arm

$$M_x = \frac{l_s}{2} x + \frac{x^2}{2} = \frac{x\,(l_s + x)}{2}$$

The chord stress is $\frac{x\,(l_s + x)}{2h}$.

The weight of the chords of length dx is

$$dW_{ch} = \frac{3{\cdot}4\,x\,(l_s + x)}{2h} \left\{ \frac{a_t}{U_t} + \frac{a_c}{U_c} \right\} dx = AM_x dx$$

Where $A = \frac{3{\cdot}4}{h} \left(\frac{a_t}{U_t} + \frac{a_c}{U_c} \right)$ ..... (4)

The shear at the distance x from the end of the cantilever arm is $S_x = \frac{l_s}{2} + x$. The stress in the web diagonals is

$$\left(\frac{l_s}{2} + x\right) \sec \beta.$$

The area of the diagonals is

$$\frac{\left(\frac{ls}{2} + x\right) \sec \beta}{U_{t_1}}.$$

The length of the diagonals with vertical posts in a length dx of the span is dx. cosec β.

The weight of the diagonals in a length dx of the span is

$$d.W_d = \frac{3.4 \times 2\left(\frac{l_s}{2} + x\right)a_{t_1}}{U_{t_1} \sin 2\beta}$$

The vertical post stress is $\frac{l_s}{2} + x$

The post section $\frac{\frac{l_s}{2} + x}{U_{c_1}}$

The length of the posts in length dx is $\frac{dx}{\tan \beta}$

The weight of the posts in the length dx is

$$\frac{3.4\left(\frac{l_s}{2} + x\right) \propto_{c_1}}{U_{c_1} \tan \beta} \cdot dx$$

The weight of the web members in the length dx is

$$d \cdot W_{web} = \left(\frac{ls}{2} + x\right) 4 \left\{\frac{2 \propto_{t_1}}{U_{t_1} \sin 2\beta} + \frac{\propto_{c_1}}{U_{c_1} \tan \beta}\right\} dx$$

The increase of the coefficients from 3.4 to 4 covers the sub-posts and the sub-suspenders not previously considered.

$$\text{Since } B_v = 4\left(\frac{2 \propto_{t_1}}{U_{t_1} \sin 2\beta} + \frac{\propto_{c_1}}{U_{c_1} \tan \beta}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

and $S_x = \frac{l_s}{2} + x$ we have

$$dW_{web} = B_v S_x dx$$

For a double system with inclined posts we obtain

$$dW_{web} = B_i S_x dx \text{ where}$$

$$B_i = \frac{4.25}{\sin 2\beta}\left\{\frac{\propto_{t_1}}{U_{t_1}} + \frac{\propto_{c_1}}{U_{c_1}}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

For the K system we have $dW_{web} = B_k S_x dx$ where

$$B_k = 3.75\left\{\frac{\propto_{t_1}}{U_{t_1}} + \frac{\propto_{c_1}}{U_{c_1}}\right\}\left\{\frac{1}{\sin 2\beta} + \frac{1}{2\tan\beta}\right\} \quad \ldots\ldots\ldots\ldots \quad (14)$$

The weight of the trusses for a length dx and unit load per foot is

$$dW_1 = (AM_x + BS_x)\,dx$$

$$= \left[A\frac{x(l_s + x)}{2} + B\left(x + \frac{l_s}{2}\right)\right]dx$$

$$W_1 = \int_{x=o}^{x=lc} dW_1 = \frac{l_c}{12}\left\{Al_c(2l_c + 3l_s) + 6B(l_c + l_s)\right\}$$

W_1 is the weight of steel in the cantilever arm required to meet the moving load stresses due to a unit load per lineal foot of bridge.

For a load μ per lineal foot of bridge we have for the weight of the trusses for the length dx

$$dW_\mu = \mu(AM_x + BS_x)\,dx$$

(To be continued.)

THE MAKING OF SOUND STEEL INGOTS.*

BY

BRADLEY STOUGHTON, Ph.B.,

Consulting Metallurgical Engineer, New York, N. Y.

THE metallurgist of to-day bears almost the same relation to steel as a doctor does to his patient. Where formerly a simple examination and a small number of tests completed a diagnosis, to-day the physician investigates the physical life history of the patient, together with some matters in the physical life of his parents and grandparents. The metallurgist also is not now content with the condition of the steel as revealed by mechanical and physical tests, but wants to be informed as to its life history during manufacture, and as to the quality of pig iron from which it was made and the conditions prevailing during the conversion and during the manufacture of the pig iron itself.

I believe that one of the greatest advances ever made in the manufacture of steel is the new system of inspection inaugurated under that great engineer and metallurgist, Robert W. Hunt, as described by him at recent gatherings of scientists.[1]

It is comparatively easy to tell by the usual tests whether the structure and composition of steel attain a given standard or quality, but certain dangerous defects, which may be inherent in the metal, will often escape the customary inspection, and may be difficult to discover even by such extraordinary investigations as sulphur-prints, microscopic examination, hardness tests, shock tests, etc., unless these are carried on at such an extensive scale as to destroy the steel for service. Defects of this character are generally classified under the head of unsoundness, and the chief ones may be described as follows:

1. Presence of blow-holes;
2. Presence of combined and occluded oxides;

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* Presented at the meeting of the Mining and Metallurgical Section held Thursday, October 30, 1913.

[1] Hunt: "Recent Developments in the Inspection of Steel Rails," Bulletin No. 72, A. I. M. E., December, 1912, pp. 1487–1495.

Hunt: "Comparative Notes on Steel Rail Rolling," Bulletin No. 77, A. I. M. E., May, 1913, pp. 879–883.

3. Presence of an unwelded shrinkage cavity; and
4. Excessive segregation.

The most effective means of preventing these elements of unsoundness is the exercise of great care and watchfulness during the manufacture of the steel, and also during the manufacture

FIG. 1.

Occluded oxide in steel.

of the iron from which the steel was made, because it now seems to be removed practically beyond controversy that certain unfavorable conditions during the smelting of iron ores in blast furnaces will produce a grade of pig iron which, during the ordinary process of manufacture, will be converted into an unsatisfactory grade of steel. It is not our purpose to discuss this matter at length in this paper, but the literature on cast iron

during the years 1913 and 1914 will afford ample proof of the accuracy of this statement. Fortunately, careful and expert inspection of the manufacturing process, and suitable testing of the product, are sufficient to prevent steel of this undesirable quality going into service.

Expert care and inspection during the manufacture and rolling of steel is also the best safeguard for preventing unsound metal from any of the other causes mentioned above going into the service of the consumer. Steel that is dangerously filled with blow-holes, or which is badly segregated, will give some indications of this condition during the ingot-forming or rolling stages. The presence of a residual unwelded shrinkage cavity can usually be prevented by proper inspection during cropping, although this is not an infallible safeguard. Oxide inclosures result from improper conditions of manufacture during the conversion of ingot-forming stages, such as: too late addition of ore to the open-hearth furnace; improper composition of the final open-hearth slag; insufficient fluidity of metal; wildness; excessive or improper addition of deoxidizers in the melt, etc.

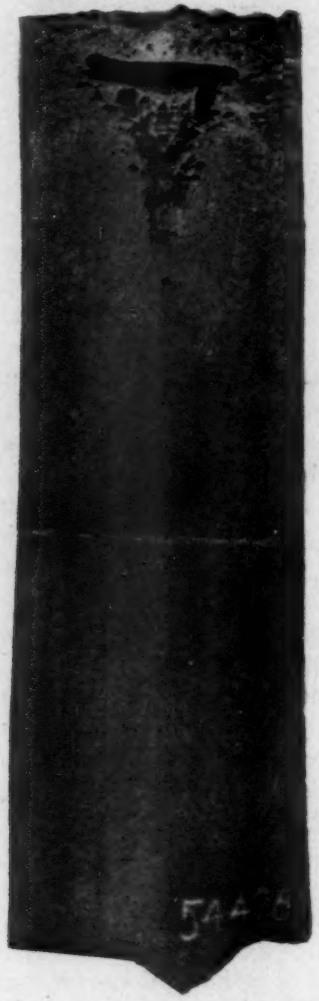
The subject of prevention of oxide inclusion has received a good deal of attention from several eminent investigators during the past two years, and a number of remedies have been suggested. The most effective means which has been extensively applied during manufacture is the addition to the liquid bath of steel of properly-proportioned quantities of titanium alloy.

Segregation does not occur to a dangerous extent when the phosphorus and sulphur are reduced to reasonable limits, provided the steel is properly deoxidized before teeming; is not wild in the moulds, and is poured in ingots not exceeding 5 to 10 tons each in weight. The larger the ingot, the smaller should be the proportion of sulphur and phosphorus in the steel, and ingots of very massive sections should not be used, unless the central core is to be drilled out and discarded, as is the case in the manufacture of large guns, for example.

The presence of blow-holes is not dangerous in low-carbon steels, except in certain situations, the causes for which are now well understood and can be eliminated. In medium and high carbon steel, the presence of blow-holes will always be indicated by the action of the liquid metal in the moulds, and suitable care in manufacture forbids such material going further in the manu-

facturing process. The careful steel-maker sends it at once to the scrap pile.

FIG. 2.

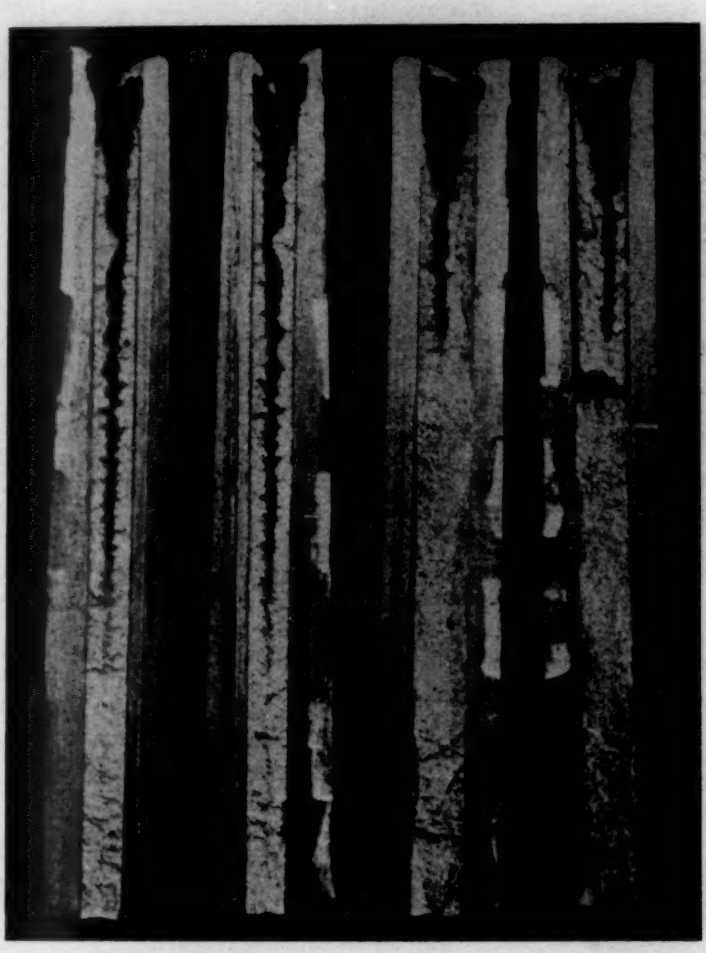


Shrinkage cavity in cut and split cold ingot.

The prevention or elimination of the shrinkage cavity in steel ingots and castings without prohibitive expense, or equally prohibitive complication in manufacture, has taxed to the utmost the

ingenuity of metallurgists, and many hundreds of thousands of dollars have been spent in experiments and investigations of

FIG. 3. FIG. 4.



Ingot cast with big end down. Uniform thickness of ingot mould walls.

Ingot having same cross-section at top and bottom and uniform thickness of mould walls.

numerous schemes and inventions. For many years the compression of the ingot during the process of solidification, in order to reduce the size of its outer envelope and thus compensate for

the shrinkage taking place during solidification, has been practised at steel works where steel of the highest quality is made. The

FIG. 5. FIG. 6.

Ingot cast with big end up. Uniform thickness of mould walls.

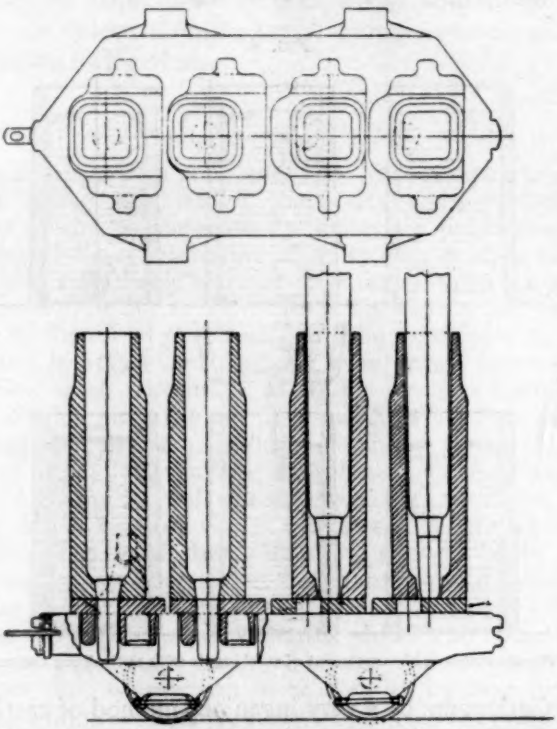
Ingot cast by Gathmann method, viz., big end up and thin mould walls at upper portion.

expense of this compression process, consisting of interest on investment, complication in the process of manufacture, and cost of operation, is not wholly compensated for by the lesser propor-

tions of the ingot which has to be converted into scrap. The compression during solidification is also claimed to improve the strength of the metal, and this claim, although not granted by all metallurgists, has some practical evidence in its favor.

An English and an American investigator have used the compression process for elimination of the pipe in a way which aims to eliminate interference with the manufacturing process and in-

FIG. 7.



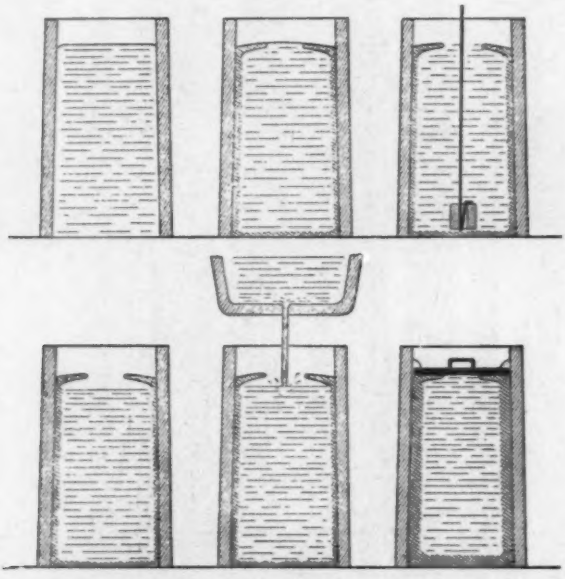
Gathmann ingot mould and stool.

terest on the investment, by taking the steel ingot before it has completely solidified and reducing its section in an ordinary pair of blooming rolls; then returning it to the heating furnace until entirely solidified, and subsequently completing the rolling operation in the usual way. Other recent investigators have aimed to accomplish a reduction in the cost of treating the steel by substi-

tuting some other method for the compression process, but none of these newer inventions secures the elimination of the shrinkage cavity, but only its reduction to a smaller size or a greater concentration at the top of the ingot, with consequent smaller proportion of cropped-off metal being necessitated.

Sir Robert Hadfield burns charcoal on top of the steel ingots in a special mould with a sand top, so as to delay the cooling of this portion of the metal and consequently draw the shrinkage cavity to that point.

FIG. 8.



Different stages in the treatment of steel ingots with anti-piping thermit.

Emil Gathmann, by a very ingenious method of casting ingots with the smaller end down and then stripping them without excessive inconvenience, as well as by distributing the metal in his ingot moulds, also produces a more rapid cooling of the lower parts of the ingot than of the top, and thereby concentrates the cavity in the upper portion.

The Goldschmidt process involves heating the metal in the top of the ingot by the well-known thermit reaction, or else by creating a stirring reaction in the ingot by means of a can of thermit,

through which, it is claimed, blow-holes, pipes, and segregation are all reduced.

Each of these cavity-reducing processes has been tried on a commercial scale long enough to prove its advantage under a given set of conditions. It is probable, however, that, in the production of very large quantities of steel, cropping off as much of the ingot as is necessary to remove the shrinkage cavity is cheaper than introducing a complication into the process of manufacture, and that careful inspection is an adequate safeguard for avoiding the dangerous defect in finished steel known as an unwelded pipe in the great majority of cases.

Alloys of Aluminum and Zinc. DR. W. ROSENHEIM and S. L. ARCHBUTT. (*Eng. Mag.*, xliii, 5, 772.)—It is widely recognized that an addition of zinc to aluminum facilitates the production of pure castings, though the zinc is said to cause the alloy to crack on cooling, and these alloys are liable to rapid corrosion. As to the corrosion, this was found to be due to impurities in the spelter, and was largely eliminated by the use of pure zinc. An alloy containing 25 per cent. of zinc could be rolled into bars and even drawn into wire. The addition of a small percentage of copper to these aluminum-zinc alloys greatly increases the tensile strength, while retaining a reasonable degree of ductility. Alloys containing from 15 to 20 per cent. of zinc are more serviceable than those containing less than 15 per cent. If dynamic as well as tensile tests are considered, the alloy containing 20 per cent. of zinc is the most generally useful of the simple binary alloys. All these alloys lose strength as the temperature rises, and cannot be forged at temperatures much above 400° C., and yet they exhibit an exceptional amount of ductility. There is a rapid fall in the yield stress and ultimate stress with rising temperature; even 50° C. produces a marked effect. Alloys containing from 10 to 30 per cent. of zinc can be worked by machine tools of all descriptions with great facility, and without the use of any lubricant in most cases.

The "Bakelite" Company. ANON. (*Metal Industry*, x, No. 9, 396.)—The General Bakelite Company has brought suits for infringement of the Bakelite patents against the Condensite Company of America, and several users of "condensite." The fundamental Bakelite patents have been allowed in Germany and have been sustained by the German Patent Office, notwithstanding that there were several public contestants.

The Volatile Constituents of Coal. A. H. CLARK and R. V. WHEELER. (*Chem. Soc. Trans.*, ciii, 1704.)—The results of further experiments support the view already advanced that coal is essentially a conglomerate of (1) degradation products of celluloses, and (2) partly-changed resins and gums of the plants from which the coal was derived. The former yield hydrogen and the latter paraffins as the main gaseous products of thermal decomposition. Pyridine effects only a partial separation of the two constituents. The pyridine extract slowly yields about one-third of its weight to chloroform or benzene when treated therewith in a Soxhlet extractor. The substance removed is a sepia-colored solid, which softens at 90° C. and partially melts at 102° C. It contains 80 per cent. of volatile matter, and on destructive distillation yields 43 to 64.5 per cent. of tar (chiefly paraffin hydrocarbons), together with gases consisting mainly of paraffin hydrocarbons and hydrogen. The portion of the pyridine extract insoluble in chloroform is similar in its properties to the portion of the original coal insoluble in pyridine, and it is considered that extraction with pyridine, followed by extraction of the pyridine extract with chloroform, will effect a complete or nearly complete separation of the resinous constituents from the degradation products of the celluloses. Russell has shown that rosin has an action on the photographic plate in the dark, and that coals have a similar action at about 50° C. It is now shown that, while the portion of coal insoluble in pyridine and the portion of the pyridine extract insoluble in chloroform have no perceptible action on a photographic plate, the total pyridine extract produces a distinct image, and the portion of the pyridine extract soluble in chloroform produces a strongly-marked image surrounded by an extensive halo.

Utilization of Coal Dust from Locomotive Smoke-Boxes. ANON. (*Eng.*, xcvi, No. 2488, 335.)—The two railway stations, Ostrowo and Skalmierzyce, which are about eleven miles apart from one another, are supplied with electricity for light and power from a power station at Ostrowo, in Prussian Silesia. The Skalmierzyce station is on the Russian frontier. The interest lies in the fact that the fuel utilized is the fuel dust which is carried through the tubes of the locomotives and collects in the smoke-boxes. This fuel is placed in gas producers to feed suction-gas engines. Similar plants have been in use for some time near Konigsberg, in Prussia. Two gas engines are installed, each of 180 horsepower, and drive two dynamos, which are independent of one another, one for each station. Current is generated at 5000 volts three-phase, and transmitted at this pressure to the Skalmierzyce station. For the Ostrowo station the current is transformed into continuous current of 230 volts. The dynamos and main conductors are provided in duplicate. Such plants are hardly likely to come into general use, but the application is interesting and may be of value in special cases.

THE FREIBERGER PROCESS OF DISCHARGING COTTON PRINTS.*

BY

ERNEST STÜTZ,

Member of the Institute.

THE art of dyeing and printing cotton fabrics has participated with all other industrial development of the last fifty years in the tendency to substitute chemical reactions for mechanical processes. The old natural dyes used more or less since the infancy of the human race have been abandoned in favor of products resulting from chemical synthesis, and the slow and cumbersome, if durable, methods of applying them to the fibre had to give way before the need of greatly accelerated and varied output. The one branch of this art which I desire to speak of here deals with the production of decorative effects by the removal of the color from the dyed, particularly indigo-dyed, fabrics by means of chemical reagents, thereby producing a pattern. This procedure, in French and German perhaps more plainly described by the equivalent of the word "etching," is known in English as "discharging." The ground color is removed where the discharge color is applied, and wherever this occurs the fabric recovers its original white tint.

In earlier days this pattern effect on the goods was generally produced by printing a so-called reserve or resist color on the undyed white material so that in the subsequent immersion of the entire fabric in the dyeing vat only the portions not printed on with the reserve showed the vat color. The reserve disappeared in the washing operation which followed, and the pattern then showed up. This method is retained to the present day in some works for certain purposes. For standard manufacture on a large scale it has been replaced by the simpler and more productive methods of discharging, the reagents used being either chromic acid (first used by Koechlin), sodium chlorate, or, in some cases, bromate. Recently the sulphoxylate method has also been pushed to the front very energetically.

* Based on a paper by M. Freiberger, *Färber-Zeitung*, vol. 24, 1913, parts 1 and 2, and communicated by the author.

Mr. Freiberger conceived the apparently very bold idea of using nitrates or nitrites as being not only very effective but also most economical discharging agents. The first attempts at putting his idea into practice were very disappointing, but, after a thorough study of all the problems entering into the question, a most efficacious and successful method was devised and brought to full industrial development, so that at the present time the nitrate process is carried out with uniformly excellent results in the largest European establishment for blue as well as calico printing.

The Freiberger method passes the cotton fabric imprinted with nitrate discharging color through hot and concentrated sulphuric acid, and by accurate control of strength, temperature, and time exposure not only preserves the fabric in its undiminished strength, but obtains the most accurate and permanent discharge effects.

A print color consisting of nitrate dissolved in starch paste does not, as is well known, discharge indigo on dyed material in dilute hot sulphuric acid, although, without a doubt, the anions NO_3 and NO_2 respectively are liberated in this case. Nitrous sulphuric acid, a solution of nitrogen oxides in concentrated sulphuric acid, for instance nitrosulphonic acid (nitrosyl sulphuric acid cryst.), NO_2–SO_3H, discolors indigo by oxidation. Beyond isatin there are said to have been shown as final products of oxidation nitrosalicylic acid, picric acid, and even oxalic and carbonic acid. These oxidation products are easily soluble in water or alkaline solutions, as, for instance, in dilute caustic soda, silicate, or soap.

First it was necessary, in the manufacture of such nitrate discharge products, to obtain conditions similar to those which prevail in the lead chambers of industrial sulphuric acid manufacture,—that is, the simultaneous presence of (1) nitrous gases, viz., nitric acid and reducing agent (there sulphurous acid) or nitrous acid (from nitrite), (2) heat, and (3) an acid of about the concentration of chamber acid. The thickeners used in the printing of nitrate colors, usually starch, already carry a substance into the sulphuric acid which acts as a developer in the discharging vat and quickly brings the free nitric acid to a lower stage of oxidation, which effect is further increased by the intentional addition of other reducing agents.

More difficult of solution was the problem of safeguarding the strength of the fibre. A cold acid of 49.5° Bé. (104° Tw.) mercerizes the cellulose about as much as concentrated caustic soda (patent application Thomas Prevost). A stronger acid produces a parchment effect by the formation of a layer of hydrocellulose and amyloid. Still stronger hot sulphuric acid carbonizes the cellulose on longer exposure, owing to water extraction. According to Schwalbe, cold acid of 40° Bé. (77° Tw.) has a weakening effect only after twenty hours, and if of 46° (94° Tw.) only after some hours, or if mixed with an equal volume of water (that is of about 65 per cent.) it has, according to Koechlin, at 46° (94° Tw.) an effect on the cellulose only after one hour. It was proved by experiments that between the limits of 36° and 45° Bé. (67–91° Tw.) good discharge effects are obtained.

According to the results of these observations the formulas were worked out which give the proper combination of monohydrate content, temperature, and time of exposure on which the success of the operation depends. The results have also been checked by numerous tensile tests. Among others, tests made at the mechanico-technical laboratory of the Technical University of Vienna in comparing nitrate discharged fabric with others treated with the best oxidation method (steaming process) gave, on divided pieces, the result that the nitrate material in one case was 5 per cent., in the other even beyond that percentage, stronger than the undischarged parts of the material.

In the case of an acid of 42° (82° Tw.) at 65° C. (149° F.), with two seconds' immersion, the print color is not fully utilized for the discharge (or, in other words, a longer discharging passage would produce a stronger discharging effect), so that a part of the nitrous acid dissolves in the discharging vat. For this reason, to protect the indigo ground it was necessary to neutralize the unused excess of nitrous combinations. In the beginning nitrous acid was supplied in the form of an addition of bisulphite. Sulphurous acid being hard to dissolve in warm sulphuric acid, organic substances, such as potato starch, were used in order to supplement the reducing effects, and, later on, cheaper materials, such as woodflock and rags. This combination fully preserves the beauty of the indigo ground, while the undischarged parts in no way suffer from the acid.

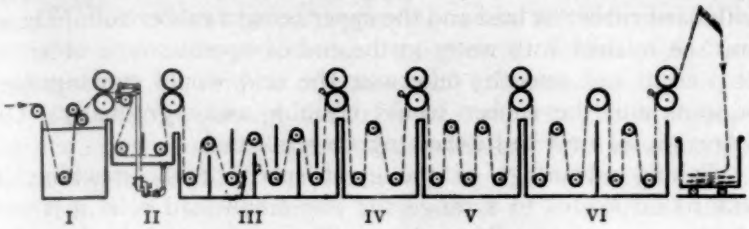
What takes place in the discharging vat may be assumed to

be a tendency of the fabric, on coming into sudden contact with the hot concentrated acid, to stiffen as in mercerization. Similarly, pieces with Prud'homme black coming out of the Mather-Platt agar are harder to the touch and also more brittle until they are washed,—that is, until the neutral reaction takes place. So long as the cotton fibre shows acid reaction it is more liable to break than in a condition of neutral reaction. This experience can be made any day in bleaching, and even a bichromate solution makes cotton more tender. A similar phenomenon may be observed when printing with a strong color containing caustic alkali, such as, for instance, Schlieper & Baum indigo color. The material appears to have lost strength. However, on thoroughly washing such printed goods the old strength not only reappears, but in many cases is increased. The same occurs in nitrate discharging. The fabric, after washing and neutralizing in dilute lukewarm alkali, shows a strength at least equal to that which it had originally.

The mechanical arrangements of the Freiberger process provide in the first vat (containing the sulphuric acid) one lower guide roller running on slide-rod bearings so as to simplify raising and lowering. Care must be taken to have this accurately adjusted in its horizontal and parallel relation to the other guiding elements. The material is drawn in either with a copper wire or a cord. With a little adroitness the operation is quickly and steadily performed, without danger of injury to the workmen. Altogether so far this discharge process has not in any single instance been the cause of injury to workmen. Once started, the apparatus runs all day quietly and evenly. In case of accidental stoppages, for instance, due to interference in the power supply, only the material in the first tank to the extent of about two yards has to be removed. The ends can be drawn in again in a few minutes. The efficiency of the machine is such that these interruptions are negligible. The length of the immersed piece, between acid surface and squeezing rolls, is about 2 to 2½ metres (about 2½ to 3 yards). Allowing 2 to 2½ seconds for the passage, the apparatus gives a speed of one metre per second, or 36,000 metres (about 40,000 yards) per ten-hour day, which is sufficient for most European works. Two workmen can run the machine, with one additional helper to start it up.

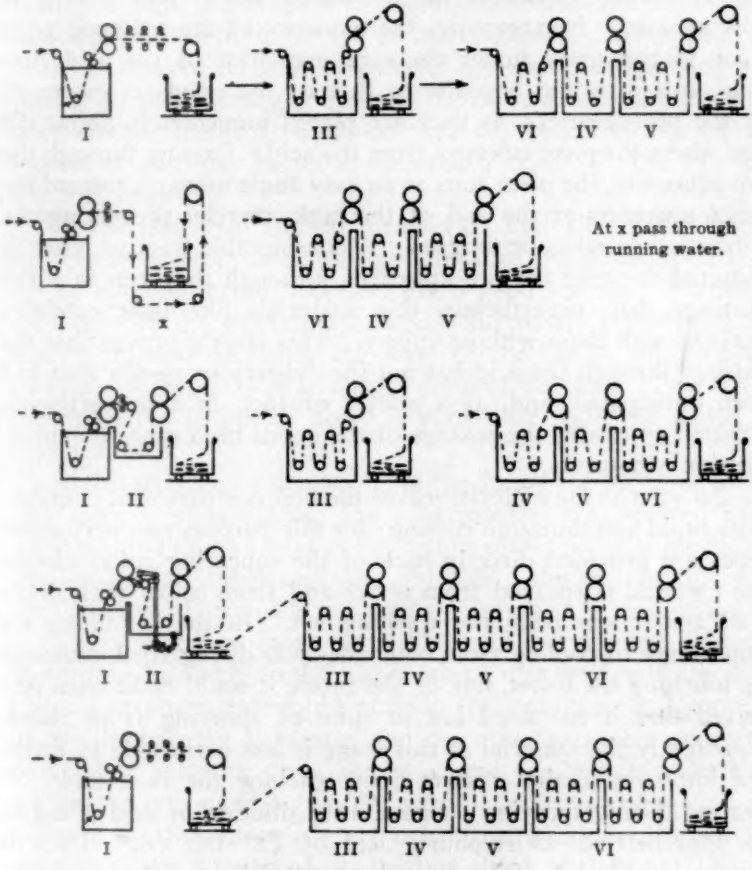
After passing the acid tank, the material is run through the

FIG. 1.



Standard apparatus for Freiberger's nitrate discharge.

I. Development bath. II and III. Regeneration and rinsing compartments.
IV. Washing compartment. V. Dilute lye. VI. Water.



Modifications of standard apparatus.

squeezing rollers, ordinary acid proof rolls, the lower being coated with hard rubber or lead and the upper being a rubber roll. These must be washed with water at the end of operations in order to keep clean and smooth; otherwise the acid would run together in spots and the rubber would crumble away gradually. Of course pieces must be stitched together, not tied.

Taking advantage of the great speed of the machine, it was found useful to arrange for two small lead rolls in front of the squeezing rolls proper. They are carried along by the material and relieve the big squeezers of an appreciable part of their work. The advantage is twofold. At high speed the squeezing impact is in the nature of a blow. This is now avoided. Furthermore, the tendency of the softened print color to run away under the spraying effect of the acid running in a direction opposite to that of the goods is overcome by the pre-squeezers, as they are placed immediately above the line where the piece emerges from the acid. Passing through the pre-squeezers, the piece runs at an easy angle upward, toward the large squeezers at the end of the tank, thereby preventing the formation of lakes or tongues. A considerable tractive effort is required to move the pre-squeezers, although they run in roller bearings, but, nevertheless, thin materials like light cambrics pass through them without injury. This clearly proves that the passage through the acid has not the deleterious results that had been anticipated, and, as a matter of fact, in a properly-constructed apparatus the passage of the goods need cause no apprehension whatever.

As soon as the material leaves the first compartment it undergoes rapid and thorough cooling; for this purpose two perforated pipes are provided directly back of the squeezing rolls, whence the material is sprayed from above and from below with dilute cold acid taken from the washing vat. In the beginning the importance of cooling from both sides was disregarded, although by touching the lower side of the fabric it could be at once perceived that it remained hot in spite of spraying from above. Apparently the material at this stage is less permeable to fluids, but improves in that respect upon reaching the next tank. A heating during spraying on account of dilution of acid is not to be apprehended, as sulphuric acid of 42° Bé. (82° Tw.) is capable of dilution without development of heat. The two spray

pipes are best provided with a separate cock each, which, after a preliminary trial before beginning work, are set once for all. This avoids waste of water and too great a dilution of the acid, the recovery of which is of economical importance.

The passage through the different compartments is regulated by the circumferential speed of the delivery rolls in accordance with requirements.

It may be assumed that 1 kilogramme (2.2 pounds) material carries along with it 800 to 900 cubic centimetres (50 to 55 cubic inches) acid from the discharging vat. By means of a small lead-lined rotary pump, installed close to and below the first rinsing trough, this is made to undergo circulation in the manner customary in diluting the lye in mercerization. What acid remains is sprayed off later by counter-current. For spraying and cooling of the discharged material the more dilute acid from the later compartments is used, so that the concentration of the recovered acid may be set at between 9° and 18° Bé. (14–30° Tw.) as required.

In the next two compartments (III and IV) the fabric is entirely freed from acid; the application of the principle of rinsing by counter-current has here given good success. Partitions are placed in the washing vat, which alternately reach from the bottom upward to nearly the level of the liquid, or from the surface downward to nearly the bottom of the tank. Two tanks, together of a length of about 4 yards, are sufficient under all circumstances.

In this passage confirmation may be found for the observation that interior strains from the acid passage are released after washing, and that as soon as the cotton enters the alkaline bath it regains its full suppleness and softness. Besides, in this case the disparity of strains is not nearly so great as in mercerization.

The acid drawn from the wash tanks can without difficulty be conveyed directly to the places where it is used, and the most efficient arrangement would provide for simultaneous operation of the discharging apparatus and the other processes using the acid. For instance, in a works where production sometimes reaches 20,000 metres (21,880 yards) a day a reservoir of a capacity of 1800 litres (63 cubic feet) was found sufficient for the temporary storage of the acid at about 9° Bé. (14° Tw.).

A small phosphor bronze injector easily distributes the acid from the reservoir to the various places of consumption.

The most obvious application of the used acid is for purposes of dilution of the technical concentrated acid to the degree proper for this process. This is done in a tank placed above the feeding reservoir, in order to have a continuous automatic flow of the acid supply. By this means one-quarter to one-third of the used acid can at once be brought back to the discharging apparatus.

The acid supply, by means of lead coils, is brought to the same temperature as the acid in the first tank. These pipe coils which run directly from the diluting tank to the cutting vat are also connected with the water system in order to allow of easy and quick regulation of the temperature. The strong recovered acid is of a faintly bluish color; it contains traces of indigo, which in the course of operations appear on the surface of the acid bath, being that portion which only loosely adheres to the fabric. The dilute acid contains also small quantities of organic matter, and of nitrogen-oxygen combinations. In the dilution of about 1° Tw. it is clear as water; it is very useful in the souring of indigo resists and of plain vat-dyed materials. The recovered acid is either diluted as required, or the regeneration process is set definitely at a fixed degree.

Practical experience has shown that the recovered acid can readily be utilized for all purposes in bleaching. It has been used for non-mercerized as well as mercerized, fine as well as heavy goods, before bowking or after chloring. The goods treated with this acid were afterward finished with the most tender uniball colors, or even plain white, or could be printed with steam colors, such as alizarin rose, light blue, or light yellow, without the slightest inconvenience.

The recovered acid is equally applicable to the souring, after soda-lye treatment, of mercerized white goods.

The preference to be given to one or the other of these methods of reusing the acid depends on local conditions.

An examination of the material as it comes out of the wash tank shows that it barely gives an acid reaction. The acid has been almost entirely retained in the two washing compartments. A calculation, based on color consumption per piece and quantity of saltpetre contained in the color, of the equivalent of free acid lost through combination with soda, will show a loss, according

to pattern and material, of from 2 to 5 per cent. of the total acid used.

In a good apparatus a recovery of over 90 per cent. of the sulphuric acid may be counted upon. If the manufacturer employs the acid first for discharging purposes, instead of sending it directly to the other consuming departments, the cost of the discharging operation, and thereby the cost of the entire process, will be very low indeed. The cost of the latter is composed of print color, lost acid, wages, and steam consumption for heating the acid, as well as motive power for the discharging apparatus. From the point of view of economy, the most efficient layout will be to provide each day that number of pieces for discharging which will be proportionate to the requirements of acid for other purposes. Should this be impracticable, it may occur that part of the recovered acid is lost. In the most unfavorable case, where the entire acid (except that part which is used to grade the supply or to dilute the fresh acid) would be lost, the cost of the development bath will still be much lower than the oxalic acid-sulphuric acid baths. This is true even in the case where the latter is diluted and is used of a low oxalic acid strength, and, as is also frequently the case, where expensive chromate color is wasted in its place. Incidentally such solutions weak in oxalic acid may be cheaper, but they give inferior results.

The method of thickening the print color has a bearing on the development of the discharge. Starch and its products, the soluble starches, give the best results; for instance, starch disintegrated to the consistency of gum by means of acetic or formic acid. Nitrate of soda gives to the starch a clear, gum-like appearance. An addition of sulphate of barium in paste form, even to the extent of a proportion of 1 : 1, is advisable, or, in the case of fine patterns, flour, tragacanth, or some leogommes. A mechanical action can be ascribed to the baryta paste, as it improves the covering white, acting as a sort of accumulator for the retention of the nitrous gases and partly preventing their premature escape by absorption. It also improves the neatness of the design, because the color is more nicely cut by the edges of the engraved lines, so that the imprint stands out better. The white paste has the additional advantage that the pattern shows up on the blue ground at the printing machine, and supervision is made easier. Part of the baryta paste is dissolved by the sulphuric acid, and

another part drops off in the subsequent washing. The remainder—and that quite an appreciable quantity—fixes itself upon the discharged white places.

The white, above all things, must be pure and clear, free from traces of undischarged blue, and standing out well from the blue ground without any bluish tinge. For the optical effect of the white it is desirable that the foundation, if possible, should not be blue but white,—that is, that the print color should penetrate and permeate as deeply as possible into the core of the fibre. With shallow or badly penetrating colors the blue ground shows through and gives to the reflected rays of light a bluish tinge. On the other hand, if a white surface is obtained by merely pasting on a white pigment, such white is not fast, as already the first washing makes it appear bluish and dirty. Nitrate white has the advantage of being pure white without any bluish tinge. A deep penetration of the color into the fibre can be easily obtained by making the consistency of the color more gummy by extensive dextrination of the starch. By contrast of the pure untinged white with the blue foundation the latter appears very bright.

For the alkaline bath (V) which follows the rinsing troughs, dilute caustic soda, or silicate, or soda may be employed. The alkali removes, on the one hand, the products of reaction from the white parts, and, on the other hand, from the indigo ground the yellow tinge it had gotten in the acid compartment, so that the indigo emerges from the treatment without any loss, undimmed and clear. The bath has now taken a light-yellow shade. The final blue of the fabric is very fine and bright and can be equalled only in the bromate process. The indigo has a from 6 to 10 per cent. stronger color effect than with other well-known methods.

In the chlorate discharging process the alkali passage makes the indigo ground paler and duller, even if a slight preliminary washing operation precedes the steaming, because in that case the alkali is charged with chlorine-oxygen combinations, while in the Freiberger process there is no danger of the indigo being injured through the alkaline solutions of nitrogen-oxygen combinations. Further, it is well known that alkaline passages have a deleterious effect if they contain a lye of excessive strength or reducing agents like hydrosulphite.

The following is a description of the process as applied to a simple example of white discharge. It is immaterial whether the goods have been dyed in concentrated or dilute, dipping vats or skying machines, or in both, whether with many or few passages, whether in light or deepest indigo shades, whether non-mercerized or mercerized, on one or both sides. The nitrates being very soluble in water, the discharging of the very finest pin-points offers no difficulty, even with the deepest and fastest dyes, and an excess of discharging agent may be dissolved in the color. After printing, the piece passes through a box with drying machine attached, from which it emerges ready dried.

Discharge White for Deep Indigo.—One ounce corn starch, ½ ounce wheaten flour, 11 ounces water, 0.12 ounce oil are boiled together; after cutting off steam, dissolve 8 ounces nitrate of soda and, at 86° F., add 10 ounces sulphate of barium paste. Make up to 2 pounds weight. Crude saltpetre used for fertilizer purposes can be employed, which is dissolved in water, filtered, and perhaps cut with a little acid before mixing and boiling with starch. As paste a wheat starch thickener is used, containing flour, tragacanth, protamol, or slightly-roasted starch, or the following: 3 ounces corn starch, 3 ounces tapioca flour, 2½ ounces acetic acid 9° Tw., ½ ounce oil, 23 ounces water; boil up to 176° F., hold at this temperature for 10 to 15 minutes, then cool and make up to 2 pounds weight. Sulphate of baryta paste may be added in the proportion of 1:1. Printing had best be done with the addition of the sulphate of baryta paste, the above-mentioned strong color being diluted with paste in the proportion of 20 to 50 per cent. for heavy dark blue, 50 to 100 per cent. for medium blue, and even more for cadets. To always obtain reliable results it is best to work with two standard colors, one for fine materials and one for heavy goods, containing 20 or 40 per cent. paste.

Development after Printing.—The printed pieces are passed for two or three seconds through the cutting vat containing sulphuric acid at 42° Bé. (82° Tw.). This is lead lined and heated indirectly by means of lead coils. Behind this follows a second compartment where the acid is recovered from the goods by spraying the wash water against them. A third compartment serves to clean the discharged parts and to neutralize the acid residue still clinging to the fabric. This is followed by a water

rinser, and in connection with it a squeezer and drier. The goods pass the machine without interruption from morning until night, the acid of the required strength being automatically renewed. The acid is never let out of the discharge trough, and is constantly ready for further use. Fig. 1 shows an apparatus of standard construction, which may be simplified as per Fig. 2 in order to utilize some already existing machinery.

The color prints with a simple pattern roller all day long without attacking the pressure drum or doctor blades or clogging the pattern. Other print colors cover the ground with fine blade scratches, and these are visible only after steaming, but in the finished piece the ground has then a disturbed appearance or the blue comes out pale and faint. The nitrate colors do not attack either the goods or the back cloth and can be kept for weeks without spoiling.

The print color is very cheap. One kilogramme (2.2 pounds) costs for deep indigo 12 pfennig (3 cents), for medium blue 9 pfennig (2 cents), and for light blue 6½ pfennig (1½ cents). Printed goods and printed back cloths can await discharging operation indefinitely. Hence there is no objection to using new goods for back cloths; they do not suffer either at the edges or in the centre. Printed goods can be kept in any manufacturing part of the building. Where a dry room is not available, nitrate of potash may be used in place of nitrate of soda with good success. In case of errors in printing, washing in water will clean the goods and they can be printed over again.

The white discharged places remain unchanged during storage and uniformly white; they contain no trace of either oxy- or hydro- or hydrated cellulose, which was proved by the well-known tests on several samples having a white discharge several centimetres wide.

Such white discharged goods are suitable to be printed over and for coloring of alumina mordants with alizarin red as well as printing with basic colors.

The method facilitates production on a large scale. Owing to the particular printability of the colors, printing can be regulated to proceed as quickly as the machine can operate. The acid tank, on account of the short distance the goods have to travel in it, can be made to conform to the greatest speed of any cloth washer,—for instance, a capacity of 36,000 metres (40,000

yards) or more per ten-hour day. Half an hour after printing, the goods are already fit for finishing. This gives the advantage to the printer that, while yet printing, he can see the goods fully developed.

The running of the machine does not create the idea of danger in the minds of practical men. Failure is no more to be feared if directions are properly followed, and normal supervision, such as is entrusted to any reliable workman, is exercised, than in passing cotton through fire in singeing or exposing it to caustic soda solutions under pressure during bowking. Every supply tank of acid is checked once with the hydrometer, and in most works this is done only once a day, before commencing operations. It has been shown by experience that the temperature can be maintained without difficulty during several hours' operation, as a supply of 1500 litres (396 gallons) in the tank and supply holders is sufficient for a full day's production.

The supervision consists of preparing the acid just as in chromate and regulating the temperature before and during operations. Inferior goods cannot be produced, as in case of improper operation or carelessness the apparatus will not work. The passage is therefore automatically regulated and checked.

As compared to other processes, the cost on medium blue, based on actual European working figures in large establishments, taking nitrate at 100 per cent., is for chromate 242 per cent. more, for chlorate 308 per cent. more, for bromate 706 per cent. more, or, even if all acid, except that serving to dilute the technical acid to 42° Bé. (82° Tw.), is lost, 70 per cent., 105 per cent., and 300 per cent. more.

For dark indigo stronger and therefore more expensive discharge colors are used, or, in the case of chromate, more expensive discharge baths. In this case, taking again nitrate at 100 per cent., chromate costs 229 per cent. more, or, in case of loss of the sulphuric acid, 127 per cent. more.

The economical results of the new method justify its introduction in small as well as large works. The saving will soon pay for the cost of installation. The product will compare very well, as regards appearance, quality, and uniformity, with those of any other method now in use, whether discharge or resist. Particular attention may be called to its uniformity, as in that respect most processes are deficient and it is an important point

with the buyer. The adherents of the reduction method like to insist on the presumed danger from the acid passage. It was in order to refute these apprehensions by the results of several years' practical and successful operation that the inventor postponed giving his process the wider publicity it deserved.*

In order to investigate possible changes of the cotton into oxy- or hydrocellulose in a practical manner, a large quantity of the worst and earliest experimental pieces from the year 1909 were made into dresses and blouses. After much laundering and constant wear these are to-day,—that is after three years,—in good and fit condition. After such tests, and considering that by now more than 10,000,000 yards have been discharged with nitrate, this process may safely be taken up by manufacturing plants as a tried and approved method.

* Previous references: Dr. Franz Erban, "Entwickelung der Oxydations Ätzen in der Blaudruckerei," *Chemiker Zeitung*, No. 67, 1910. M. Felix Binder, "Rongeage de l'Indigo à l'aide des composés oxygénés de l'azote," *Bulletin Annuel de l'Ass. Gén. des Chimistes de l'Industrie Textile*, Paris, 1911.

Influence of Drilling Holes on the Strength of Soft Steels. ANON. (*Amer. Mach.*, xxxix, No. 14, 555.)—Tests made at the École Centrale, Paris, are reported in "Le Génie Civil" to show that when holes are drilled and then reamed in soft-steel bars the metal materially increases in strength, the average limit of elasticity improving 12.3 per cent. and the average tensile strength 9.2 per cent. This phenomenon is explained thus: In putting together the parts of a test piece broken under tension, it is found that the two ends do not coincide; and that, while the edges make a good contact, the central parts do not, thus indicating that the rupture begins at the centre, and that the edges have a higher tensile resistance than there is along the axis of the bar. Therefore, if several holes are drilled so as not to injure the material too much, as might be the case with punching, the average tensile strength of the section across the holes, per unit of metal, will be higher than before the holes were drilled, since each hole creates, so to speak, additional edges.

Action of Finely-Divided Nickel on Nitric Oxide. R. S. FELGATE. (*Chem. News*, cviii, 178.)—Nitric oxide was circulated through hot water containing in suspension finely-divided nickel, prepared by reducing the dry precipitated hydroxide by hydrogen. The nickel was rapidly oxidized and nitrogen was formed. Colloidal nickel prepared by Bredig's method of electrical disintegration failed to produce a similar result.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NOTE ON THE SETTING OF A MERCURY SURFACE TO A REQUIRED HEIGHT.

By M. H. Stillman.

(*From Bulletin of the Bureau of Standards.*)

A COMMONLY-EMPLOYED method of setting the mercury surface in the cistern of a barometer of the Fortin type is to raise the mercury surface relative to the downward-projecting ivory pointer until the end of this pointer makes a minute dimple in the surface. It has been found that the setting can be made more easily and with much greater precision by placing on the side of the cistern opposite to the observer a scale consisting of alternate horizontal black and white lines, each line being about 0.5 mm. wide, so that the image of this scale may be seen in the mercury surface at the place where the contact will occur. Before contact occurs the lines of the image are practically uniform in width and parallel; but as soon as a very minute dimple is formed the fact is made known by the distortion of the lines of the image in the immediate vicinity of the point of contact. The fact that the distorted part of the image is surrounded by an undistorted field of parallel black and white lines of uniform width makes the distortion very easy to detect.

Experiments were made to determine with what precision settings of a mercury surface could be reproduced by this method. In a sample set of five consecutive readings the greatest deviation from the mean was 0.0007 mm., while the average deviation from the mean was 0.0003 mm. Even closer agreement of settings was obtained when the illumination and the condition of the observer's eyes were more favorable.

The accuracy with which settings could ordinarily be reproduced by using the method of noting the apparent coincidence of the end of the pointer and its image was also investigated and

* Communicated by the Bureau.

found to be less than by using the improved method just described.

The mercury surface, when set by the ordinary dimple method, is higher relative to the pointer than when set by noting the apparent coincidence of the end of the pointer and its image. The improved dimple method gives a setting between those given by the ordinary dimple method and the method making use of the apparent coincidence of the end of the pointer and its image. In ordinary barometry the differences in settings by the various methods are generally negligible, but in very precise work they should be considered.

The improved method should be especially valuable where it can be applied to reading both ends of a mercury-column; for when used in this way the constant errors of the settings cancel, thus allowing the great sensibility of the method to be realized.

THE VISCOSITY OF PORCELAINS.

Technologic Paper by A. V. Bleininger and Paul Teetor.

THE vitrification of porcelain in the pottery kiln is made possible by lowered viscosity or softening and surface tension which contracts the mass, thus eliminating the pore space. Since no numerical values are available with reference to the degree of softening of porcelain bodies, a series of mixtures were prepared and their viscosity determined at a number of temperatures, between 1160° and 1310° C. The deformation under tensile strain was used as a measure of viscosity. The previously-fired test pieces of suitable shape were suspended from fire-clay grids, and clay weights corresponding to a load of five pounds per square inch attached. After each successive firing to a higher temperature the elongation due to the tensile load was accurately measured. By inspecting the numerical values with reference to composition, it is found that complete vitrification is not possible with less than 19 per cent. of feldspar. Excess of feldspar is undesirable owing to the lowered viscosity brought about by it. The higher the kaolin content, the less marked does the effect of feldspar become. A sharp line of demarcation appears between the bodies containing less than 45 per cent. clay and those of higher clay content. The

former possess a very much higher temperature coefficient of viscosity decrease and hence are more subject to deformation. A lower clay content than 45 per cent. is hence undesirable and may explain the difficulties experienced with bodies of the Seger porcelain type. The strength of porcelain bodies under tensile stress, at the kiln temperatures considered, has been found to be quite low, approaching five pounds per square inch quite closely with maximum elongation, and is but a small fraction of the tensile strength at ordinary temperatures. As to the permissible numerical elongation value under a load of five pounds per square inch, no exact deductions can be made, but it probably lies between five and six per cent.

This method of studying bodies is capable of producing valuable results, and might, with advantage, be applied to clays and other mixtures.

THE ACCURACY OF THE FORMULAS FOR THE RATIO, REGULATION, AND PHASE ANGLE OF TRANSFORMERS.

Paper by P. G. Agnew and F. B. Silsbee.

A DETAILED investigation of all the approximations involved in the derivation of the following formulas for ratio, regulation, and phase angle shows that they are as accurate as are required by the precision with which the quantities involved may be experimentally determined:

N = ratio of turns, primary to secondary.

E_1, E_2 = primary and secondary terminal voltages.

$R = R_1 + N^2R_2$ = equivalent total resistance referred to the primary.

$X = X_1 + N^2X_2$ = equivalent total reactance referred to the primary.

I, I_0 = load current and exciting current referred to the primary.

$\cos\theta$ = power factor of load.

$\cos\gamma$ = power factor of exciting current.

When $\pm$ signs occur the upper sign should be used for lagging and the lower sign for leading current. A positive phase angle means the reversed secondary leads the primary.

$$\text{Ratio} = N\left[1 + \frac{IR\cos\theta \pm IX\sin\theta}{NE_2} + \frac{(IR\sin\theta \mp IX\cos\theta)}{2NE_2^2} + \frac{I_0R_1\cos\gamma + I_0X_1\sin\gamma}{NE_2}\right]$$

$$\text{Per cent. regulation} = 100\left[\frac{IR\cos\theta \pm IX\sin\theta}{NE_2} + \frac{(IR\sin\theta \mp IX\cos\theta)^2}{2NE_2^2}\right]$$

$$\text{Phase angle} = \frac{1}{E_1}\left[\begin{matrix} IR\sin\theta - IX\cos\theta + I_0R_1\sin\gamma \\ - I_0X_1\cos\gamma \end{matrix}\right]$$

For most practical work the square terms in the formulas for ratio and regulation may well be omitted.

To test the formula, direct measurements were carried out on two types of lighting transformers by means of the potentiometer method, and covering the whole range of power factors from zero power factor current leading to zero power factor current lagging. The results checked with the values computed by means of the formula from short-circuit and open-circuit data, well within the experimental errors.

POLARIMETRY.*

IN the preparation of this circular two principal objects have been sought: *First*, to put before the public in as concise a form as possible a general view of polarimetry, especially as applied to the testing of sugars; and, *second*, to collect together into a single paper such information in regard to instruments and methods of procedure as may be obtained only by an extended study of the literature on the subject. Much of the data is taken from standard works, but many of the points discussed are treated with the aid of information obtained from the researches carried on at the Bureau of Standards. A considerable portion of this information has not before been generally available.

A short historical sketch of the development of polarimeters is given, followed by a discussion of light sources, in which it is proposed to make the mercury-green line, $\lambda = 546.1\mu\mu$, the standard in polarimetric work instead of the sodium line, $\lambda = 589.25\mu\mu$. The ratio of the rotations of the two lines for quartz equals 0.85074. Points in the design of the Bates type saccharimeter and the effect of different white light sources on saccharimetric

* Abstract Circular, No. 44, 1913.

readings are discussed. The influence of temperature, also, is fully considered. Care must be taken in applying temperature corrections, especially in the polarization of raw sugars. For temperature control at the Bureau of Standards special small thermostats and a thermostated room are used. The latter may be adjusted for any temperature between 15° C. and 40° C., with a maximum variation of 0.3° C. A new polariscope tube is described which is made entirely of metal and rests on shoulders, thus eliminating all danger of unduly tightening the caps when the tube is rotated in the trough of the instrument.

Especial attention is paid to the analysis of raw sugars, and a number of methods are given. The question of clarification is taken up quite fully, and the advantages and disadvantages of the various means pointed out.

A method for the preparation of pure sucrose has been worked out and is described, as are also the methods used for determining the purity of the final product.

The Bureau is prepared to distribute samples of pure sucrose and of pure dextrose. It is also prepared to make tests on any instrument or substance used in polarimetry or saccharimetry which is included in the schedule of test fees listed. Polarimetric work not included in the schedule will be undertaken by special arrangement.

The paper is quite fully illustrated, containing several photographs and a number of diagrams showing the apparatus in detail.

In the appendix are given the U. S. Treasury Department Sugar Regulations and twenty-four tables, collected from various sources, which are of use in the average laboratory.

Niello or Nielled Silver. ANON. (*Brass World*, ix, 10, 347.)—Niello was known hundreds of years ago, and was apparently lost sight of, but came in use again lately. The method of manufacture is: An article of sterling silver or a silver alloy is deeply engraved in the usual manner. The cuts of the engraved design are then filled with silver, copper, and lead *sulphides*. This mixture of sulphides is black and adheres tenaciously to the silver, and instead of the deep engraving there appear black lines. The sulphide is fused into the silver and is the most permanent black known on account of its thickness. Niello is now rarely found in the trade. The best qualities come from Russia and command a high price. The manufacture of Niello dates back to the eleventh century; and Percy, the celebrated

English metallurgist, states an account of it was written by Theophilus or Rugerus, a monk of that period. The mixture used in Russia and Persia for enamelling silver jewelry is stated to be:

	Ounces.	Drachms.
Silver	0	4
Copper	2	4
Lead	3	4
Sulphur	12	0
Ammonium chloride	2	4

Make a paste of the sulphur with water and put it in a crucible. Melt the metals and pour them into the crucible which contains the paste. Cover this, so that the sulphur may not inflame, and then calcine till all excess sulphur is volatilized. Finely pulverize the mass; and make a paste with a solution of ammonium chloride, and rub this paste into the parts to be enamelled. Clean the article and heat it in a furnace until the paste melts and adheres to the metal. Moisten the article with a solution of ammonium chloride and heat in a muffle to redness. The article, when cold, can be rubbed and polished without detaching or altering the enamel, which retains its fine black color.

The proportions of the metals used at various times were:

Authority	Silver. Per cent.	Copper. Per cent.	Lead. Per cent.
Pliny	75.00	25.00	——
Theophilus	66.67	22.22	11.11
Biringuccio	16.67	33.33	50.00
Benvenuto Cellini	16.67	33.33	50.00
Blaise de Vigenére	16.67	33.33	50.00
Perez de Vargas	16.67	33.33	50.00
Georgi (in Russia)	7.69	38.46	53.85
Répertoire of Patent Inventions, 1827	5.88	35.30	58.82

The sulphur and ammonium chloride are used as previously described. It is noticeable that the oldest Niello mixture contains the most silver and no lead, while lead is the principal ingredient in the latest. The foregoing method of making nielled silver is costly, since each article must be engraved. It might be cheapened by engraving in relief a steel plate and compressing it against a silver plate between two hard bodies. A great many copies may be obtained from the same matrix.

Gas Engines versus Natural Gas as Fuel. ANON. (*Amer. Mach.*, xxxix, 5, 176.)—When natural gas is used as a fuel under a steam boiler, from 40 to 60 cubic feet per horsepower-hour are required, while the same power can be developed in a gas engine by the consumption of from 9 to 15 cubic feet; so the use of gas under steam boilers is not to be encouraged, if indeed it should be permitted. (From the *Compressed Air Magazine.*)

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, December 17, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 17, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 12.

The following proposed amendment to the By-laws was presented for first reading:

Article III, Section 10 of the By-laws to be amended as follows:

After "Philadelphia" in the second line add: "except that members of the Army and the Navy shall be considered as non-resident members, irrespective of residence," so that the section, as amended, shall read:

"Non-resident members shall be those who reside permanently at a distance not less than twenty-five miles from Philadelphia, *except that members of the Army and the Navy shall be considered as non-resident members, irrespective of residence.* Transfers of membership from the resident to non-resident class may be granted by the Board of Managers at its discretion in cases of temporary absence of a member from the city for a period of not less than one year."

The following nominations were made for officers and managers to be voted for at the annual election to be held January 21, 1914:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Coleman Sellers, Jr.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), John Birkinbine, Walton Forstall, E. Goldsmith, Harry F. Keller, Louis E. Levy, Richard Waln Meirs, Alexander P. Robinson, and George D. Rosengarten.

For Manager (to serve two years), Marshall S. Morgan.

Mr. J. A. P. Crisfield, Chairman of the Committee on Science and the Arts, then introduced Mr. C. Francis Jenkins, of Washington, D. C., who had been recommended by the Institute to the City of Philadelphia for the award of the John Scott Legacy Medal and Premium for his motion-picture apparatus. The Chairman presented the medal to Mr. Jenkins.

Dr. David T. Day, in charge of Petroleum, Division of Mineral Resources, United States Geological Survey, Washington, D. C., was then introduced and presented the paper of the evening on "Petroleum and Its Derivatives."

The speaker described the present state of the petroleum industry, and gave interesting facts and statistics relating to the wells in California, Texas, Pennsylvania, and other parts of the United States. The subject was illustrated by lantern slides, and numerous specimens of oils from various localities were exhibited. After the address an interesting demon-

stration of moving pictures, showing the operations of boring for oil, the shooting of the well, and the gushers in action, was given.

On motion of Mr. Levy, duly seconded, the thanks of the meeting were extended to Dr. Day.

Adjourned.

R. B. OWENS,
Secretary.

RESOLUTION ADOPTED BY THE BOARD OF MANAGERS ON THE COMPLETION OF MR. ALFRED RIGLING'S THIRTIETH YEAR AS LIBRARIAN OF THE INSTITUTE.

The Board of Managers of The Franklin Institute, taking note of the completion, on February 13, 1913, of thirty years' continuous service by Alfred Rigling in the library of the Institute, unanimously resolves that there be recorded in the minutes of this Board the following memorial of that anniversary:

> The Board of Managers takes this occasion to express its unqualified approbation of the zealous and efficient service rendered to the Institute by its Librarian, Alfred Rigling, and those of its present members whose collaboration in the activities of the Institute extends back to the earlier years of Alfred Rigling's time take this occasion to add in their own behalf, and as voicing the sentiments of colleagues now passed away, a note of high appreciation of the faithful devotion to duty exemplified by Alfred Rigling in his work as Librarian of the Institute throughout all this course of years.
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> The Board, furthermore, unanimously resolves that this memorial be published in the JOURNAL of the Institute and that an engrossed copy thereof be presented to the Librarian.

Adopted, September 10, 1913.

ISAAC B. THORN SCHOLARSHIPS IN INSTITUTE'S SCHOOL OF MECHANIC ARTS.

Due to the generosity of Miss Mary Thorn, of Philadelphia, the Institute is able to announce the establishment of the above scholarships in memory of her father, an early member of the Institute and for many years a participant in the Institute's activities.

The sum of one thousand dollars has been deposited in trust, the interest of which is to be used for free scholarships in the Departments of Mathematics, Mechanics, and Naval Architecture.

Miss Thorn has also deposited with the Institute a further sum of three hundred dollars for the establishment of a Permanent Resident Membership.

The Board of Managers by resolution acknowledged these gifts on November 12th and extended the thanks of the Institute to Miss Thorn.

COMMITTEE ON SCIENCE AND THE ARTS.

PRESENTATION OF THE JOHN SCOTT LEGACY MEDAL AND PREMIUM TO HALCOLM ELLIS.

The John Scott Legacy Medal and Premium was presented to Mr. Halcolm Ellis, Mechanical Director of the Ellis Adding Typewriter Company of Newark, N. J., at the stated meeting of the Institute held Wednesday, November 19th, for his adding typewriter.[1]

Dr. George A. Hoadley, in presenting the recipient of this recognition to the President, said:

"The Franklin Institute has been fortunate in having friends who believe in expressing their friendship in a practical way. It is for this reason that the Directors of the Board of City Trusts of the City of Philadelphia have delegated to The Franklin Institute the honor of presenting to those men and women who have made useful inventions the John Scott Legacy Medal and Premium.

"Some years ago the typewriter made its appearance and won its place in our business life. A few years after that the adding machine and the calculator found their places in our business requirements. Both of these devices have now become invaluable.

"Since that time inventors have been trying to devise a machine that would do the work of both these machines at the same time, so that a person using the typewriter might immediately take up the calculating work without the necessity of leaving the machine.

"Such a machine has been built. The knowledge of this invention having come to The Franklin Institute, the matter was turned over to the Committee on Science and the Arts for investigation. The committee recommended that an investigation be made on the merits of this invention. It was found to be a machine which, although made of many parts, had in it simplicity of design and operation; a machine that had in it a feature that is noticeable in all American-made machinery—interchangeability of parts; a machine of practical value.

"Following the favorable report of the Committee on Science and the Arts, The Franklin Institute recommended to the Board of City Trusts the award of the John Scott Legacy Medal and Premium to the inventor of this machine.

"It therefore gives me great pleasure to present to you Mr. Halcolm Ellis, inventor of the combined adding and typewriting machine."

PRESENTATION OF THE JOHN SCOTT LEGACY MEDAL AND PREMIUM TO C. FRANCIS JENKINS.

On recommendation of the Institute, Mr. C. Francis Jenkins, of Washington, D. C., was awarded the John Scott Legacy Medal and Premium for his motion picture apparatus.[2] The presentation was made at the stated

[1] J. F. I., December, 1913, p. 723.

[2] Page 95.

meeting of the Institute held Wednesday evening, December 17, 1913, and in presenting the recipient to the President of the Institute, Mr. J. A. P. Crisfield, Chairman of the Committee on Science and the Arts, said:

"Before presenting to you the subject which the managers of the Institute have provided for our instruction and amusement this evening, I desire to announce to you that we will first perform one of our time-honored and most respected ceremonies, namely, the recognition by the Institute of the meritorious work of an inventor.

"The Certificate of Merit of The Franklin Institute has ever been a highly-prized possession, but when accompanied, as it will be to-night, by a medal of enduring metal, paid for through the self-denial of one who has long since joined his fathers, the recipient of this recognition by the Institute is doubly honored.

"The man who will receive to-night these awards for a useful invention, cunningly conceived and skilfully executed, has probably done more to perfect the moving-picture machine and to widen its field of usefulness than any other.

"This simple statement should be sufficient to excite in us a feeling of gratitude to him who has so largely contributed to our amusement and education by materially assisting in bringing the moving-picture machine to its present high state of development. Mr. President, I take pleasure in introducing to you Mr. C. Francis Jenkins, of Washington, D. C."

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 3, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 3, 1913.

MR. J. A. P. CRISFIELD *in the Chair.*

The following report was presented for final action:

No. 2537.—Cooper Hewitt Mercury Arc Rectifier. Elliott Cresson Medal. Adopted.

The following reports were presented for first reading:

No. 2539.—Duplex Copper Steel Wire. Advisory. Adopted.

No. 2540.—Upton Lewis Fatigue Testing Machine. Deferred.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Thursday, November 13, at 8 o'clock P.M., with Dr. George A. Hoadley in the chair. One hundred and three members and visitors were present.

The minutes of the previous meeting were read and approved.

P. W. Bridgman, A.M., of the Jefferson Physical Laboratory of Harvard University, delivered an address on "High Pressures and Five Kinds of Ice."

The cylinder, piston, packing, and pressure gauges used in studying the action of exceedingly high pressures upon water were described. The region of each of the five kinds of ice, one of which exists as a solid at 160° F., was shown by means of curves and lantern slides. New phases or allotropic modifications of phosphorus, carbon tetrachloride, and other compounds, discovered by a study of their behavior at high pressures, were also mentioned.

The paper was discussed at length, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Wednesday evening, November 26th, at 8 o'clock.

Mr. J. A. P. Crisfield, member of the Institute, and Mr. Clarence P. Wynne, President of the Aëro Club of Pennsylvania, presided jointly.

Mr. Crisfield introduced Dr. A. F. Zahm, of Washington, D. C., who, in a paper entitled "Recent Developments in Aëromechanics," gave an account of the most recent researches in aëromechanics in the principal European laboratories.

The paper was illustrated by about fifty lantern slides.

After some discussion, the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, December 4th, at 8 o'clock.

Professor A. E. Outerbridge, Jr., and Mr. A. R. Cheney presided jointly.

Professor Outerbridge introduced Mr. D. A. Lyon, A.M., Metallurgist, United States Bureau of Mines, Washington, D. C., who presented a paper entitled "Some Present-day Metallurgical Problems."

The speaker dealt with the extensive application of the electric furnace, the utilization of slag, fuel economy in smelting, and the question of iron and steel corrosion. He outlined the possibilities for invention in the smelting of sandy, sulphuretted, and complex ores. He concluded with remarks on direct-process methods of smelting, without intermediate steps.

After some discussion, the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, December 11th, at 8 o'clock. Dr. Walton Clark presided.

The minutes of the previous meeting were approved as published.

The Chairman introduced Mr. J. Waldo Smith, C.E., Chief Engineer, Board of Water Supply, New York City, who presented a paper on "The Catskill Water Supply for New York City."

Mr. Smith described the construction of the ninety-two-mile aqueduct for bringing water from the Catskill Mountains to New York City. By means of lantern slides, he illustrated the making of the tunnel, cut and cover, and open portions of the aqueduct, showing the methods employed in reinforcing the structure, particularly the deeper portions, as, for instance, where it passes under the Hudson River.

After some discussion the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting of the Board of Managers, December 10, 1913.*)

RESIDENT.

MR. LEWIS J. STERN, 1805 Spring Garden Street, Philadelphia, Pa.

NON-RESIDENT.

MR. ONWARD BATES, 332 South Michigan Avenue, Chicago, Ill.

MR. JOHN W. CLOUD, 82 York Road, King's Cross, London, N., England.

MR. R. T. CRANE, III, Crane Company, 836 South Michigan Avenue, Chicago, Ill.

MR. E. R. FELLOWS, Fellows Gear Shaper Company, Springfield, Vt.

MR. A. L. JOHNSON, Corrugated Bar Company, Mutual Life Building, Buffalo, N. Y.

MR. GUSTAV LINDENTHAL, 68 William Street, New York, N. Y.

MR. HUNTER MCDONALD, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

MR. AUGUSTUS SMITH, foot West Fifth Street, Bayonne, N. J.

MR. H. R. STANFORD, U.S.N., Chief of Bureau of Yards and Docks, Navy Department, Washington, D. C.

ASSOCIATE.

MR. ALLEN DOUGLAS IRVINE, 523 Commercial Trust Building, Philadelphia, Pa.

MR. ATHERTON H. MEARS, Spencer Street, Logan Station, Philadelphia, Pa.

Changes of Address.

MR. ALFRED E. BURK, 925 North Third Street, Philadelphia, Pa.
MR. G. W. CHANCE, 3421 North Eighteenth Street, Philadelphia, Pa.
MR. JOHN W. HORNSEY, Searles, Cal.
MR. NELSON B. MAYER, Hotel Marie Antoinette, Broadway and Sixty-seventh Street, New York City.
MR. ERNEST. H. RIGG, 51 Delaware Street, Woodbury, N. J.
MR. J. WALDO SMITH, Municipal Building, New York City.

LIBRARY NOTES.

Purchases.

BRUNSWIG, H.—Explosives. 1912.
COLVIN, F. H., and L. L. HAAS.—Jigs and Fixtures. 1913.
DYKE, A. L.—Dyke's Automobile Encyclopedia. Ed. 3. 1913.
GIBSON, C. R.—Wireless Telegraphy and Telephony. 1914.
HAYES, H. V.—Public Utilities. 1913.
JONES, H. C.—New Era in Chemistry. 1913.
KARAPETOFF, V.—The Electric Circuit. 1912. Ed. 2.
LINDGREN, W.—Mineral Deposits. 1913.
LOW, A. H.—Technical Methods of Ore Analysis. Ed. 6. 1913.
MCCULLOCH, G., and T. C. FUTERS.—Winding Engines and Winding Appliances. 1912.
PRIMROSE, J. S. C.—Practical Metallography. No date.
RAMBOUSEK, J.—Industrial Poisoning. 1913.
RECTOR, F. L.—Underground Waters. 1913.
REED, S. J.—Turbines Applied to Marine Propulsion. 1913.
REGENBOGEN, C.—Building of Diesel Engines at Krupps'. 1913.
SEGERBLOM, W.—Tables of Properties. 1909.
SMITH AND WARREN.—New Steam Tables. 1912.
SMITH, E. F.—Elements of Electrochemistry. 1913.
SMITH, E. F.—Theories of Chemistry. 1913.
SMITH, E. F., and H. F. KELLER.—Experiments for Students in General Chemistry. 1913.
SPRINGER, J. F.—Oxy-acetylene Torch Practice. No date.
STILL, A.—Overhead Electric Power Transmission. 1913.
SYDNEY, S.—Mechanical Refrigeration. 1913.
TAYLOR, W. T.—Transformer Practice. Ed. 2. 1913.
TOLMAN, W. H., and L. B. KENDALL.—Safety Methods. 1913.
WAKEMAN, W. H.—Pumps and Pumping Machinery. 1912.
WHITE, A. H.—Techinal Gas and Fuel Analysis. 1913.
WOODWARD, C. M.—Rational and Applied Mechanics. 1912.

Gifts.

American Society of Civil Engineers, Transactions, vol. 76. 1913. New York, 1913. (From the Society.)

Australia Bureau of Census and Statistics; Official Year Book, No. 6. 1913. Shipping and Oversea Migration for 1912. Melbourne, 1913. (From the Bureau.)

Baltimore & Ohio Railroad Company, 87th Annual Report, 1913. Baltimore, 1913. (From the Company.)

Barlow's Tables of Squares, Cubes, etc. London, 1897. (From Mrs. H. C. Heckendorn.)

Canada Department of Customs, Report March 31, 1913. Ottawa, 1913. (From the Department.)

Canada Department of Mines: Memoir No. 37, Portions of Atlin District, British Columbia, by D. D. Cairns. The Production of Copper, Gold, Lead, etc., in Canada during 1912 and Summary Report of the Mines Branch for 1912. Ottawa, 1913. (From the Department.)

Canadian Society of Civil Engineers, Transactions, vol. 27, pt. 1. 1913. Montreal, 1913. (From the Society.)

Colgate University, Autumn Bulletin, The College. Hamilton, N. Y., 1913. (From the University.)

Council of Arts and Manufactures of the Province of Quebec, Rules and Regulations of the Free Drawing and Industrial Classes, 1913–1914. Montreal, 1913. (From the Council.)

Fleming, J. A.—Alternate Current Transformer. London, 1894. (From Mrs. H. C. Heckendorn.)

Great Britain Board of Trade, 16th Abstract of Labour Statistics. London, 1913. (From the Board.)

Great Northern Railway Company, 22d Annual Report, June 30, 1911. St. Paul, 1913. (From the Company.)

Hopkins, G. I.—Manual of Plane Geometry. Boston, 1891. (From Mrs. H. C. Heckendorn.)

Houston, E. J., and A. E. Kennelly.—Recent Types of Dynamo Electric Machinery. New York, 1898. (From Mrs. H. C. Heckendorn.)

Hutchinson, W. B.—Patents and How to Make Money out of Them. New York, 1899. (From Mrs. H. C. Heckendorn.)

India Inspector General of Forests, Annual Return of Statistics Relating to Forest Administration in British India, 1911–1912. Simla, 1913. (From the Inspector General.)

Institution of Naval Architects, Transactions, vol. 55, 1913, pt. 1. London, 1913. (From the Institution.)

Isthmian Canal Commission, Canal Record, vol. 6, 1912–1913. Ancon, Canal Zone, 1913. (From the Commission.)

Kapp, G.—Electric Transmission of Energy. London, 1891. (From Mrs. H. C. Heckendorn.)

Manchester Steam Users' Association: Boiler Explosions Act, 1882. Board of Trade Reports 2073–2178. London, 1913. (From the Association.)

Massachusetts Institute of Technology, Catalogue December, 1913. Boston, 1913. (From the Institute.)

Mellon Institute of Industrial Research and School of Specific Industries, Bulletin No. 3, Psychological Aspects of the Problem of Atmospheric Smoke Pollution, by J. E. W. Wallin. Pittsburgh, 1913. (From the Institute.)

Minneapolis Water Works, Annual Reports of the Registrar and Supervisor, 1912. Minneapolis, Minn., 1913. (From the Works.)

New Jersey Geological Survey: Bulletin 10, The Mechanical and Chemical Composition of the Soils of the Sussex Area, New Jersey. Bulletin 11, The Mineral Industry of New Jersey for 1912. Trenton, 1913. (From the Survey.)

New York State Library, 94th Annual Report, 1911. Albany, 1913. (From the Library.)

Oklahoma Geological Survey, Bulletin No. 11, Gypsum and Salt of Oklahoma, by L C. Snider. Norman, 1913. (From the Survey.)

Ontario Bureau of Mines, 22d Annual Report, 1913, pt. 1. Toronto, 1913. (From the Bureau.)

Ontario Department of Agriculture: Annual Report of the Bee-Keepers' Association, 1912, and Annual Reports of the Dairymen's Associations, 1912. Annual Report of the Farmers' Institutes, 1913, pt. 2. Annual Report of the Women's Institutes, 1913, pt. 1. Toronto, 1913. (From the Department.)

Peabody Institute, 46th Annual Report, 1913. Baltimore, 1913. (From the Institute.)

Pennsylvania: Vetoes by the Governor, 1913. Report of the State Librarian, 1912. Laws of Pennsylvania, 1913. Message of the Governor of Pennsylvania to the General Assembly, January 7, 1913. Annual Report of the Superintendent of Public Printing and Binding, June 30, 1912. Annual Report of the Secretary of Internal Affairs, pt. 4, June 30, 1912. Pennsylvania Report of the Commissioner of Banking, 1912, pt. 1. Harrisburg, 1913. (From the State Librarian.)

Pere Marquette Railroad, Annual Report, 1913. Detroit, no date. (From the Railroad.)

Pratt and Whitney Company, Precision Tools. Hartford, Conn., 1904. (From Mrs. H. C. Heckendorn.)

Raynes, F. W.—Heating Systems. London, 1913. (From Mrs. H. C. Heckendorn.)

Royal Society of London, The Celebration of the Two Hundred and Fiftieth Anniversary, July, 1912. London, 1913. (From the Society.)

Slingo, W., and A. Brooker.—Electrical Engineering. New York, 1898. (From Mrs. H. C. Heckendorn.)

Smith College, Catalogue 1913–1914. Northampton, Mass., 1913. (From the College.)

Standage, H. C., comp.—Cements, Pastes, Glues, and Gums. London, 1897. (From Mrs. H. C. Heckendorn.)

Vermont Historical Society, Proceedings 1911–1912. Montpelier, 1913. (From the Society.)

Western Reserve University, Reports of the President and Other Officers, 1912–1913. Cleveland, 1913. (From the University.)

Wisconsin Agricultural Experiment Station, 29th Annual Report, 1912. Madison, 1912. (From the Station.)

Yonge, C. D., comp.—English-Greek Lexicon. New York, 1886. (From Mrs. H. C. Heckendorn.)

PUBLICATIONS RECEIVED.

Le Chatelier, Henry.—Eau oxigénée et ozone. Memoires de Thénard, Schoenbein, de Marignac, Soret, Troost, Hautefeuille, Chappuis. Les Classiques de la Science, vol. iii. 111 pages, plate, 12mo. Paris, Armand Colin, 1913. Price, 1.20 francs.

LeMoine, Jules.—Mesure de la Vitesse de la Lumière. Étude optique des Surfaces. Mémoires de Léon Foncault. Les Classiques de la Science, vol. ii. 123 pages, plates, 12mo. Paris, Armand Colin, 1913. Price, 1.30 francs.

Rein, H.—La Technique de la Radiotélégraphie. Traduit de l'Allemand d'apres la deuxième édition par G. Viard. 262 pages, illustrations, plates, 8vo. Paris, Gauthier-Villars, 1913. Price, 9 francs.

Canada, Department of Mines, Summary Report of the Mines Branch for the Calendar Year Ending December 31, 1912. 174 pages, illustrations, plates, maps, 8vo. Ottawa, King's Printer, 1913. Price, 15 cents.

Ontario Bureau of Mines, Twenty-second Annual Report 1913, being vol. xxii, pt. 1. 284 pages, illustrations, maps, 8vo. Toronto, King's Printer, 1913.

Pennsylvania Topographic and Geological Survey, Report of the Work Accomplished during the Fiscal Years Ending June 30, 1911, and June 30, 1912. 182 pages, illustrations, plates, maps, 8vo. Harrisburg, State Printers, 1912.

United States Secretary of Commerce, Annual Report, 1913. 151 pages, 8vo. Washington, Government Printing Office, 1913.

Canada, Department of Mines, Mines Branch: The Production of Iron and Steel in Canada during the Calendar Year 1912, by John McLeisch, B.A., Chief of the Division of Mineral Resources and Statistics. 39 pages, 8vo. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada during the Calendar Year 1912, by Cosmo T. Cartwright, B.Sc., Assistant Mining Engineer, Division of Mineral Resources and Statistics. 86 pages, 8vo. Ottawa, Government Printing Bureau, 1913.

United States Bureau of Mines: Bulletin 69, Coal Mine Accidents in the United States and Foreign Countries, compiled by Frederick W. Horton. 102 pages, 8vo. Bulletin 70, A Preliminary Report on Uranium, Radium, and Vanadium, by Richard B. Moore and Karl L. Kithil. 101 pages, illustrations, plates, map, 8vo. Miners' Circular 13, Safety in Tunnelling, by David W. Brunton and John A. Davis. 19 pages, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, September and October, 1913, with revised figures for preceding months, compiled by Albert H. Fay. Technical Paper 30, Mine Accident Prevention at Lake Superior Iron Mines, by Dwight E. Woodbridge. 38 pages, illustrations, 8vo. Washington, Government Printing Office, 1913.

Mellon Institute of Industrial Research and School of Specific Industries, Smoke Investigation Bulletin No. 3, Psychological Aspects of the Problem of Atmospheric Smoke Pollution, by J. E. Wallace Wallin, Ph.D., Director of Psychological Clinic, University of Pittsburgh. 46 pages, 8vo. Pittsburgh, University of Pittsburgh, 1913.

United States Department of Agriculture: Bulletin No. 9, An Economic Study of Acacias, by Charles Howard Shinn, Forest Examiner. 38 pages, illustrations, plates, 8vo. Office of Public Roads: Report of the Director for the Fiscal Year ended June 30, 1913. 13 pages, 8vo. Washington, Government Printing Office, 1913.

Hodges, Leroy.—Training for Citizenship. An article on the Winston-Salem plan of training for citizenship. 5 pages, 8vo. Washington, Government Printing Office, 1913.

New Method of Preparing Argon. J. STARK. (*Phys. Zeitschr.*, xiv, 497.)—When oxygen issues from a cylinder into a vacuum tube containing mercury vapor a reddish-yellow deposit of mercury oxide appears on the glass. The canal-ray spectrum shows mercury and strong argon lines, but little oxygen and no nitrogen. The commercial oxygen obtained by the evaporation of liquid air contains about 6 per cent. nitrogen and 4 per cent. argon. The oxygen and nitrogen combine with the mercury in the glow discharge and leave the argon free. A simple arrangement is described for utilizing this process in preparing spectroscopically pure argon. Not only are nitrogen and oxygen rendered active by the glow discharge, but also hydrogen and iodine vapor.

CURRENT TOPICS

International Electrical Congress, San Francisco, 1915—The International *Electrical* Congress is to be held at San Francisco, September 13th to 18th, 1915, during the Panama-Pacific International Exposition, under the auspices of the American Institute of Electrical Engineers, by authority of the International Electrotechnical Commission. Dr. C. P. Steinmetz has accepted the honorary presidency of the Congress. The deliberations of the Congress will be divided among twelve sections, which will deal exclusively with electricity and electrical practice. There will probably be about 250 papers. The first membership invitations will be issued in February or March, 1914.

Attention is drawn to the distinction between this Electrical Congress and the International *Engineering* Congress which will be held at San Francisco during the week immediately following the Electrical Congress. The Engineering Congress is supported by the Societies of Civil, Mechanical, and Marine Engineers and by the Institutes of Mining and Electrical Engineers, as well as by prominent Pacific Coast engineers who are actively engaged in organizing it. This Congress will deal with engineering in a general sense, electrical engineering subjects being limited to one of the eleven sections which will include about twelve papers, treating more particularly applications of electricity in engineering work.

The meeting of the International Electrotechnical Commission will be held during the week preceding that of the Electrical Congress.

New Use for Aluminum. ROBERT GRIMSHAW. (*Metal Industry*, x, No. 9, 380.)—Leon Guillet, in a paper read before the French Society of Civil Engineers, called attention to two new forms of aluminum which have recently been used in large quantity, viz., the production of aluminum powder and aluminum foil. The powder is produced from the foil. Aluminum foil is gradually displacing tin foil for wrapping articles of food such as cheese, and especially chocolate. Long and expensive experiments were conducted before a means was found to roll the metal sufficiently thin. According to *La Nature*, the rolling is effected in the factory at La Praz in six stages, the last of which yields a foil which is only 0.04 mm. (0.0016 inch) thick. In order to get a still thinner foil several sheets are laid together and either rolled as a whole or beaten, as is done with gold leaf. To make aluminum powder, foil only 0.01 mm. thick (0.0004 inch) is cut into squares of 2 mm. on the side and rubbed to powder. This powder is used to make aluminum paint. It feels like salve, or rather like graphite, and is very difficult to remove from the hands.

Phosphate Industry of Egypt. ANON. (*Board of Trade J.*, Sept. 4, 1913.)—The exploitation of the phosphate deposits in Egypt was commenced in 1908, and the growth of the output of phosphates since then is shown by the following figures: In 1908, 700 tons; in 1909, 1,000 tons; in 1910, 2,397 tons; in 1911, 6,425 tons; in 1912, 69,958 tons. As there is no factory in Egypt for the manufacture of superphosphates, and as the local demand for phosphates as fertilizer is at present negligible, practically all the phosphate mined is now exported. There are many low-grade deposits, however, which may in time become of commercial value if a demand should arise for raw phospate as a fertilizer.

The Combustion of Gaseous Mixtures and Retardation on Ignition. TAFFANEL and LE FLOCH. (*Comptes Rendus*, clvi, 1544.)—The course followed by the combustion of mixtures of methane and air is studied by introducing small quantities of the mixtures into an evacuated silica flask which has 300 c.c. content and is heated electrically. By means of a special cock, which opens and closes automatically, this introduction is effected in less than 0.03 second, and 0.05 to 0.12 second after the shutting of the cock the mean temperature of the gas differs from that of the wall of the flask by only about 10°. A registering manometer records photographically the variation of pressure in the flask as a function of the time. The ignition of mixtures of methane and air, which is rendered evident by the flash and also by a sharp rise in pressure, occurs only after the lapse of a certain time, varying with the temperature of the flask and with the composition of the gaseous mixture. This retardation is observed also with moist mixtures of the gases, so that the usual explanation—that explosive combustion requires the presence of a certain quantity of water—falls to the ground. It seems rather that the velocity of reaction of these gaseous mixtures increases with the temperature less rapidly than with mixtures which exhibit no such retardation.

Production of Diamonds in Electric Furnaces. F. P. MANN. (*Met. and Chem. Engin.*, xi, 361.)—Gives an account of the experiments made by E. de Boismenu at Paris in 1908 and described by him in a pamphlet entitled "Fabrication Synthétique du Diamant." Fused calcium carbide is electrolyzed for hours in an electric furnace fitted with two horizontal carbon electrodes 24 cm. apart. "Enriched" carbide is afterward found near the anode; farther away the carbide is undecomposed, but near the kathode a black mass of carbon is observed, from which a few flakes of graphite and some irregular, colorless crystals or globules can be isolated, which were pure carbon, according to Lacroix and Maquenne. The length of the crystals increased with the duration of the electrolysis, from 1.5 mm. in six hours to 2.7 mm. in twelve hours. The process is covered by French Patent No. 4566 of August, 1907.

New Multiple Relations of the Atomic Weights of Elementary Substances; Classification and Transformations of Neon and Helium. H. WILDE. (*Manchester Lit. and Phil. Soc. Mem.*, lvii, Part 3, No. 12.)—In several of the author's papers on the "Origin of Elementary Substances" special attention was directed to the seventh series of his classification, on account of the magnitude and importance of its primary members in the economy of nature, namely: nitrogen, silicon, gold, and iron. Silicon in combination with oxygen constitutes more than half the weight of the earth's crust. The arbitrary policy of several writers in doubling the atomic weights of four of the gaseous members of this series (neon, argon, krypton and xenon) induced the author to review the multiple relations of the seventh series with this important result: That six triads are formed out of the eighth principal members of the series, in which the sum of the atomic weights of the extreme members is double the atomic weight of the means, and are all multiples of seven. Triads of atomic weights have been fully recognized by Dumas, Faraday, and others, as indubitable evidence of community of origin, of transmutation, and as important factors in the classification of elementary substances. Radium is one of the synthetic transformations of helium, and is the next higher member of the series to barium, as was confirmed by Mme. Curie. Helium is also shown as the analytic transformation ultimate of radium and other members of the second series of elements. The positions of helium and neon, as the transformation ultimates of the second and seventh series respectively, are further interesting in connection with the recent announcements that these elements have been found in glass vessels and tubes in which they had no previous existence. Assuming the truth of these observations, the phenomena are not only explicable by the author's classifications, but also account for the discordant results obtained by the experimenters engaged in the research. One of the investigators could only find neon, while others, working independently, found only helium, and others a mixture of both gases. These results were sufficiently interesting to induce the author to ascertain the composition of various glasses used in the arts. The principal and most important constituent of the glasses examined by the author is silicon,—the transformation ultimate of which is neon. The next important constituents are barium, calcium, and lead,—all members of the second series of elements, the transformation ultimate of which is helium. The alkali metals, sodium and potassium, are constituents of nearly all glasses, and their transformation ultimates (with others of the first series) will be hydrogen and neon, but without helium. All the silicates of the first and second, and some of other series, are easily vitrified in small quantities in laboratory crucibles. Their spectra can then be examined during electrification in tubes (under suitable conditions of temperature and pressure) for the discovery of new elements and the identification of those already known.

Magnetic Normal Triplet and Preston's Law. R. FORTRAT. (*Comptes Rendus,* clvi, 1607.)—Paschen and Black have shown that the oxygen triplet λ 3947 gives, in a sufficiently intense field, a magnetic triplet very closely approximately the normal. This paper describes a similar research with the sodium doublet λ2852.828, 2853.031. In a weak field the decomposition follows Preston's rule. In a field of 34,400 gauss two anomalies present themselves. These are described with the aid of a diagram. With a field of 44,500 gauss most of the regular components could be distinguished, but with very abnormal intensities and polarizations, and with displacements considerably greater than the errors of observation. In a field of 47,600 gauss, in place of the ten components given by Preston's rule, only a triplet is found; the side component on the short wave-length side is sharp, the central component and the other side component being broader. Measurements of the distances between the sharp line, the most intense part of the central line, and the middle of the other side line, show that the triplet is nearly normal. It appears probable that a field of 50,000 gauss would give an exact normal triplet with sharp components. Fortrat has previously shown that in certain bands the doublets and triplets are reduced by a magnetic field to a single line. This fact throws some light on the present results, since it now appears that both a doublet and a triplet behave, in sufficiently strong fields, as if formed of a single line.

Under Cooled Steam. ANON. (*Engineering,* xcv, 673.)—This paper considers the condensation of steam according to the views of Aitken, C. T. R. Wilson, and J. J. Thomson,—*i.e.*, as a result of the presence of nuclear dust, electrons, or drops of liquid. These considerations are applied to ordinary boiler steam conditions and a recent article of Stodola (in *Schweiz. Bauzeitung*) is criticised. The loss in turbine nozzles due to undercooling is, according to Stodola, not more than 1 per cent. *Engineering* disagrees, and shows that the loss may be very much more. The current view that moist steam is less efficient on account of higher friction is opposed, and undercooling with subsequent reversion to thermal equilibrium is put forward as the main cause of loss.

Recovering Oil and Waste. ANON. (*Electr. Rwy. Journ.,* xlii, 62.)—The Denver City Tramway Company cleans the oil and waste used in the car journals in a tank 5 feet 6 inches long, 3 feet 6 inches wide, and 17 inches high, in which is a horizontal screen on which the picked waste rests. Clean, hot oil is poured over the waste, and after this oil has dripped away the waste can be used again. The oil used for washing is filtered and used again. About 150 pounds of journal and armature waste are worked through the tank every week. No new waste has been purchased since December, 1912, when the plant was first used. All car motors are oiled every ten days.

Simplification of Spectral Lines by Magnetic Field. R. FORTRAT. (*Comptes Rendus*, clvi, 1459.)—Various experimenters have shown that in very strong magnetic fields certain groups of spectral lines are simplified. In this paper Fortrat describes the action of a magnetic field on certain band spectra, and shows that a large number of naturally multiple lines are simplified by the action of the field, in this case of 40,000 gauss. A diagram is given of the effect on the green band of carbon. The action of the field reduces all the doublets to simple lines, and the triplets are also reduced to simple lines for all frequencies above 1949. The blue band of the Swan spectrum gave similar results, as did also the spectrum of the negative pole of nitrogen. The phenomenon thus appears to be a general property of band spectra.

Electrical Propulsion of Submarines. G. MARIN. (*Electricien*, xlvi, 101.)—The electrical interest of submarine navigation is referred to, and it is affirmed that, but for the use of electricity, this branch of naval practice would have offered almost insuperable difficulties. It is imperative that the propelling machinery should be as efficient and compact as possible, while being absolutely reliable. Silent and flexible operation is required, and it is desirable that no exhaust gases should be expelled which might disclose the position of the vessel to an enemy. The constancy of weight of the vessel where electricity is employed is a further advantage. The general problems encountered in the electrical propulsion of submarines resemble those of storage battery traction on land. Two independent battery, motor, and control equipments are generally provided, one on each side of the vessel; the capacity of each motor in modern submarines being about 800 horsepower. In port the batteries may be charged from a central station supply, but at other times the motors are driven as dynamos by the oil or steam engines used for surface propulsion. In respect of flexibility and reliability steam engines are preferable to oil engines, but the former require boilers and involve further weight and space difficulties. The *Gustave-Zédé* has two Belleville engines of 1500 horsepower, and the use of steam turbines in submarines is now considered. Electrical energy is generally distributed and employed at 240 volts pressure in modern submarines; higher voltages would be advantageous but for the difficulty of maintaining insulation in the humid atmosphere within a submarine and the undesirability of high-tension apparatus in the limited space available. The Siemens-Schuckertwerke have provided 440-volt supply on board the *Vulcan*. Submarines of nearly 1000 tons displacement have been built, and much larger vessels are under construction. Traction-type batteries are used to store maximum energy in minimum space. The following values are given for weight and cost (per one kilowatt-hour capacity on three-hour discharge) of various types of accumulators: Lead (Planté), 73·5

kg./196 fr.; lead (pasted), 62 kg./200 fr.; lead (high capacity), 56 kg./190 fr.; Edison (iron-nickel), 42 kg./340 fr. The lead accumulator is the only type used, so far, in submarines, but the Edison cell, though costly, offers advantages in respect of lightness, compactness, strength, freedom from sulphation, and avoidance of acid. Practical experience is required to determine whether the Edison cell is advantageous in such large sizes as are required for submarine work. Speed regulation by field control is convenient and efficient; it may be combined with series-parallel control, the latter being applied not to the two main motors, but to the two armature windings of a double commutator motor or to the two halves of each battery. The starboard and port batteries, control gears, and motors are generally kept quite independent. The main switch-gear is of the contactor type, controlled by master switches; graduated electro-dynamic braking is provided for the motors. It is usual to specify 90 per cent. full-load efficiency for the motors of a submarine carrying two 590-kilowatt machines; the electrical losses in the motors then amount to 118 kilowatts at full load; further heating is caused by the starting rheostats, which may attain 200° C.

Analyses of Coals in the United States. N. W. LORD. (*United States Bureau of Mines, Bulletin 22.*)—This contains analyses of 5000 samples of coal taken from 1500 coal mines. The purpose of the bureau in compiling and publishing this information is to give reliable data regarding the chemical composition and thermal value of the coals. The samples were collected by experienced men according to a definite and uniform system, and were analyzed under carefully-controlled conditions, so that there might be no question as to the relative merits of the different coals so far as this can be determined by chemical analyses and determinations of the heating values.

New Torque Meter. H. GÖRGES and P. WEIDIG. (*Elektrotechn. Zeitschr.*, xxxiv, 701.)—This mode of measurement is an improvement on the brake principle, as it transmits instead of absorbing the energy. A flexible coupling of the Siemens-Schuckert type, connected by leather rings, is used for transmitting the energy. Suitable mirrors are mounted on the spindles on each side of the coupling. The first mirror receives light from a source, reflects it to a second external mirror, which then reflects it again to the one which is mounted on the other side of the coupling, from which it is transmitted to the eyepiece of a telescope. Supposing that no torque is being transmitted, the eyepiece receives an image of the source of light, but when the torque is transmitted, either the telescope or the source of light must be displaced in order that the image may be received on the eyepiece. The amount of this displacement is a measure of the torque.

Incandescent Gas Light Chimneys in the Flame. ROBERT SCHALLER. (*J. Gasbel.*, lvi, 317.)—The Jena works have produced a new glass called "Suprax" for lamp chimneys. If a piece is heated in a pointed blast flame, till a circular spot is softened, then cooled, and the heated spot scratched with a diamond, only one sample out of many cracked, while all other glasses submitted to the same test cracked badly. Devitrification, formation of a dusty coating of sodium sulphate from the sulphur in the gas, and the formation of copper red spots from particles of brass from the burner, are given as faults of the old glasses, and this new glass is stated to be much more resistant to similar action than any other.

Production of Radio-active Substances from Thorium. F. GLASER. (*Chem. Zeit.*, xxxvii, 1105.)—The precipitation of thorium X from a thorium solution obtained from monazite sand with sulphuric acid is conditioned by the presence of lead which, as lead sulphate, absorbs thorium X, and thorium X may be separated from any thorium solution containing sulphuric acid by the addition of a little lead acetate. Other lead salts do not behave like lead sulphate in this respect, so that by treating the radio-active lead sulphate with sodium carbonate solution, dissolving the washed residue in hydrochloric acid, and precipitating with hydrogen sulphide, the lead may be separated as sulphide, leaving thorium X in solution.

Influence of the Sizing of Paper on the Resistance of the Text of Documents to Removal by Mechanical or Chemical Means. H. FREDERKING. (*Mitt. K. Material-Prüfungsamt*, xxxi, 195.)—The harder the surface sizing and the closer the surface texture of the paper, the more readily are written, typewritten, or stamped characters removed. A striking exception to this rule is the case of parchment papers, from which characters in writing ink can seldom be removed entirely without trace. Such papers, however, hardly fall within the range of practical application for documents. As a guard against falsification, document papers should be relatively soft-sized. Papers sized with resin are to be preferred, from this point of view, to papers sized with gelatin, because certain of the chemical ink-removing agents leave stains on resin-sized papers. The prejudice against typewriting for documents is scarcely justified, since many brands of modern typewriter ribbons give characters as difficult to remove as characters written in ink, sometimes even more resistant. The treatment of documents with a protective varnish is of little value as a safeguard against falsification; such varnishes cause the spreading of typewritten or stamped characters and are only available for documents written in ink. With hard tub-sized papers the varnish remains on the surface and is easily removed by solvents, while with softer-sized papers the protection afforded by the varnish is so slight that it does not compensate for the unsightly appearance produced.

The Humphrey Pump. H. A. HUMPHREY. (*Engineering*, xcv, 708.)—The author suggests various modifications. An experimental plant has shown practically the same efficiency at high as at low lifts, and a continental licensee has devised an arrangement for securing good compression pressure under a low delivery head. The use of air vessels is indicated, and a symmetrical arrangement of two pumps suggested. An adaptation is described by which heavy oils may be used with an externally-heated carburettor. The oscillating mass of dead water may be replaced by a metallic piston. This gives the same inertia with much less bulk, and by this method the rate of reciprocation has been increased to 193 cycles per minute. Curves are given showing the thermal efficiency of the pump cycle contrasted with that of the Otto cycle gas engine at various compression pressures.

The Displacement of the Critical Points of Iron by the Addition of Silicon. G. CHARPY and A. CORNU. (*Comptes Rendus*, clvii, 319.)—The point a_3 occurs at a slightly higher temperature and becomes less marked as the silicon content rises, and disappears at about 1.5 per cent. silicon. The point a_2 occurs at a lower temperature as the silicon increases, but does not change in intensity. In low carbon steels the fall is 10° to 12° C. for 1 per cent. silicon. The point A_1 rises slightly on the temperature scale as the silicon increases. It tends at the same time to become less marked, in consequence of the transformation of the carbon into graphite in presence of the silicon, and disappears when the silicon exceeds about 5 per cent. The extent to which the carbon is transformed into graphite, and hence the intensity of the a_1 transformation, is partly determined by the heat treatment. In steels with more than 3.2 per cent. silicon, a_1 is higher than a_2 on the temperature scale.

Recovery of Lost Handwriting by Photography. A. JENCIC. (*Wiener Mitt.*, 1913, 299.)—Ultraviolet light photography is of limited availability, but as most ancient and modern inks are acid, the following methods are often successful. Nitrated silver chloride paper is kept in contact with the faded text for 12 hours or more, then exposed to full light, when the writing shows in metallic lustre on a dark ground. The image cannot be fixed, but is stable enough for examination. If the silver chloride paper after exposure is fumed with the vapor of burning phosphorus in a closed chamber the writing becomes visible. Solio or similar paper, after contact with faded writing, will show an image if mercury be poured on it from a height of about 30 cm. and the paper be immersed in dilute ammonia. The paper after contact may also be exposed 15 minutes to direct sunlight and then pressed against a dry plate, which can subsequently be developed with dilute rodinal. If the manuscript be dampened a weak solution of hydrogen peroxide will often assist.

Some Properties of Industrial Electrolytic Iron. L. GUILLET and A. PORTEVIN. (*Compt. Rend.*, clvi, 702.)—The metal on coming out of the electrolyte is saturated with hydrogen and is very hard. When heated for two hours in magnesium oxide it loses a great part of its hardness. The critical points obtained by heating are 791° and 937°; those obtained by cooling are 902° and 778°. The critical points of heated metal are practically the same. In the crude metal there is an absorption of heat at 530° and 590°, which points do not appear on cooling or reheating, being evidently due to the presence of hydrogen. Conductivity tests on raw iron give 10.22 microhms, while the treated metal gives a value of 11.92 microhms, these abnormally high values being due to hydrogen in the metal.

Action of Various Substances on Concrete. R. K. MEADE. (*J. Ind. Eng. Chem.*, v, 723.)—Experiments with test briquettes prepared from cement-sand (1 : 13) mixtures are described, which show that the addition of barium compounds or iron compounds (red brick dust, etc.) is ineffective for preventing or appreciably retarding the disintegrating action of magnesium salts and sulphates on concrete. Disintegration is retarded somewhat by application of various waterproofing materials, especially lime soap and lime soap and alum. Cements of low alumina-content withstand the action of magnesium sulphate solution much better than those containing a larger quantity of alumina. Experiments with mineral oils showed that no destructive action is likely to take place where cement is used for floors in machine shops and engine-rooms.

The Chemistry of Boiler Scale Prevention. EDGAR T. WHERRY and GEORGE S. CHILES. (*Eng. Mag.*, xlv, 518.)—Many substances are used to prevent boiler scale. According to the usual theory, definite reactions must occur between these and the calcium and magnesium salts in the water to produce any effect. The results obtained in practice do not confirm this view, either in that the substances used are often incapable of causing such reactions, or the amounts necessary are much less than would be required. When the calcium and magnesium compounds first separate from the water they are colloidal, and their hardening to form scale is due to their becoming crystalline. Protective colloids might be expected to prevent this change, and it is pointed out that most of the substances used are capable of acting in this capacity.

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